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Jean Baptiste André Dumas

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SCIENTIFIC WORTHIES

XIV.—Jean Baptiste André Dumas

"Qui vero utraque re excelleret, ut et doctrinæ studiis et regenda civitate princeps esset, quis facile præter hunc inveniri potest?"—*Cicero.*

THE age in which we live is pre-eminently distinguished by the widely-spread culture which it bestows on science, and especially on the natural sciences. At no former time has the number of scientific investigators even approached that of those who are at present enthusiastically cultivating every field of human inquiry. But concurrently with the increase of scientific work in the aggregate, the field of labour has been restricted within narrower limits for individuals. Very many inquirers of the present day are only distinguished in a single department of science—often, indeed, in a single section of that department, to the investigation of which they devote their whole efforts, without directing their attention to any achievements in other branches—nay, often abstaining from taking any note of those achievements, because doing so might interfere with exclusive absorption in the special subject of their own study.

While we are far from withholding due recognition and sympathy from those who are working for the advancement of science within such narrow limits, either prescribed to them by circumstances or voluntarily imposed upon themselves—while we are willing to attribute the marvellous development of science at the present day, in part at least, to that very self-limitation—yet our eye fixes with incomparably greater interest on those who, having acquired the mastery of various and extensive branches of science, are enabled from the higher point of view thus gained to take a comprehensive survey of the whole domain of human inquiry. And if a man who has attained so high a position in science has also shown a hearty interest in the public affairs of his country—if he has not disdained to descend into the arena of daily life—to devote his time and strength, the stores of his knowledge and the faculties of his judgment, matured by long experience, to the service of his fellow-citizens, he is sure of our unstinted admiration, and we trace the course of his life and labours with lively interest, not only from the pleasure we feel in the conquest he has won for all mankind, but also because a glance at the obstacles he has had to surmount in his career encourages us to persevere and to press forward more zealously on our own path, at whatever distance and however slowly we may follow the steps of our great precursor.

Such a man is Dumas, the celebrated chemist, whose life-like portrait is given to the public with this day's number of NATURE. Beginning in early youth as a student of pharmacy, he participated, even during his pupilage, in physiological researches which are looked upon as models of deep and accurate observation. But soon turning aside to devote himself to chemistry—a science which is indebted to him for the establishment of a series of fundamental truths, which he has enriched with admirable methods of research adopted in all laboratories, and which he has carried forward on lines of progress followed by chemists even to this day—he has been for more than thirty years the leading representative of that science in the great schools of Paris. Nor has this eminent scientific position prevented him from exercising a powerful influence upon the public affairs of his country, which he has served successively as Deputy to the Legislative Assembly, as Minister of Agriculture, as Senator, as President of the Paris Municipal Council and as Master of the Mint of France. From early manhood he has been a member of the Academy of Sciences, and later, by a rare combination, a member also of the French Academy; and even now, on the threshold of his eightieth year, in full force and with almost youthful freshness, he fulfils the functions of permanent secretary to the Academy of Sciences. Identified in these several positions with the progress of science in his native country during half a century, Dumas has gone through an amount of active and diversified labour such as few men of science now living can boast.

Jean Baptiste André Dumas was born at Alais, in the department of the Gard, July 14, 1800.

His father came of an ancient family which, at the revocation of the Edict of Nantes, had separated into two branches. Of these the Protestant branch had emigrated, while the Catholic, to which he belonged, had remained in France. He was an accomplished man, fond of literature and the arts; he possessed considerable skill in drawing, and even practised painting very successfully. A stay of several years in Paris had enabled him to see a good deal of the society of his time. At a later period he had settled in his native place, where he held the position of clerk to the municipality.

The little town of Alais was almost unknown at the beginning of this century, being inhabited by only a few thousand souls. Nevertheless, young Dumas found there everything conducive to the expansion of a youthful intellect and to the development of a well-built frame.

A college which had then no lack of pupils fulfilled the requirements of the boy's early education, initiating him more especially in the study of Latin, so congenial to the classical traditions of the neighbourhood. It would, indeed, be difficult to imagine a country more likely to create and foster a taste for the history and language of Roman antiquity than the province in which Alais is situated. It is well known that the south of France was a cherished conquest of the Romans, and that numerous monuments of their long occupation of the land still remain; but there are few places, even in the south of France, exhibiting a finer array of relics than the country surrounding Dumas' birth-place. Indeed, the young scholar had only to ascend, for a comparatively short distance, the Gardon river, which traverses the town, to behold one of the most imposing remains of antiquity, the noble Pont du Gard, with its three superposed tiers of lofty arches, which at one time carried the water of the springs of Airan across the valley. Those who have once visited the celebrated aqueduct will never forget the magnificent outlines of this grand structure, as in solitary majesty it spans the desolate valley. Not far from Alais are the cities of Nîmes and Arles, the Nemausus and Arelate of the ancients: the former, with its splendid amphitheatre, and with its Corinthian temple

—the far-famed *Maison Carrée*—in a rare state of preservation; the latter boasting of a glorious arena and the ruins of a Roman play-house. These cities, it is true, were not, at the beginning of this century, as near to Alais as the railway has since brought them, yet they were not sufficiently distant to be inaccessible to the ardent youth during his holiday excursions.

These associations could not but have had a tendency to direct the mind of young Dumas to the study of the past; but there were other influences, not less potent, continually calling him back to the present. Indeed, the town of Alais, by its unique situation, afforded opportunities of observing nature and the processes of adapting her products to the use of man, which proved not less attractive to the future academician. Both in his speeches and writings he frequently refers with gratitude to these varied impressions of his early youth at Alais.

The existence of coal-fields in that neighbourhood was known as far back as the commencement of this century, and a few coal-mines were actually being worked at that time, though it was impossible to convey the coal in waggons over ill-kept roads to any great distance. The coal trade could not, therefore, in any way be compared with that which nowadays is carried on with such activity in that part of the south of France; still, that important source of power had even then given rise to numerous local industries. There were glass-works at the very gates of Alais, exhibiting to the passer-by the several processes of manufacturing glass. In its vicinity were brick-yards, tile-works, and manufactories of coarse earthenware; so that opportunity of becoming familiar with the working of clay and the other operations of the ceramic arts was not wanting. Still nearer to the town large quantities of lime were burnt in kilns, which were fed with limestone quarried by blasting, whilst higher up the Gardon mines of iron pyrites supplied the materials for manufacturing green vitriol. Not far from the town, mines of antimony were in operation, furnishing a material which was fused and run into cakes, to be sold in the market of Alais. Mines of argentiferous lead ore were worked in several places. Iron ores abounded, waiting only for the bold hand of the smelter. Lastly, in the Gardon and in the Cèze, gold in spangles was met with, and zealously sought by the gold-finders after every rain-storm, at the licensed shoots which stop the particles detached by a natural process of washing from the side of the mountain, and have no doubt done so from remote antiquity.

Situate at the outskirts of the Cevennes, the neighbourhood of Alais produces all the varied crops of southern countries. Towards the plain below the town, which is flooded each autumn and spring by the river swollen with diluvial rains or with the melting of the mountain snow, verdant meadows and rich pasture-lands are seen rivalling in luxuriant growth those of northern climes, while the slopes of the hills are studded with mulberry trees, pines, and olives. Towards the mountain, on the other hand, the walnut and chestnut make their appearance.

In this charming country varied and picturesque harvest scenes occur from month to month. The breeding of the silk-worm, and the process of winding off the cocoon, the hay-making, the corn harvest, the vintage, the gathering of the olive crop, and the preparation of the oil, the walnut picking, the collecting and drying the chestnuts—each in turn excite curiosity and invite observation. The varied vegetation of a land which adjoins Provence, which reaches to the Mediterranean, and is, as it were, the *avant-garde* to the snow-capped mountains of Lozère, allows the comparison, in a few short excursions, of purely southern with maritime and alpine vegetation. No wonder that a friend of Linnæus, the Abbé de Sauvages, found means, without ever leaving this narrow corner, to take a foremost place among the botanists of his time.

It would be difficult to imagine a happier complement to a classical education than the lessons taught at every step in this delightful country. Nor were they lost upon young Dumas, who at fourteen years of age, in addition to his rare attainments in classical literature, had acquired a rudimentary knowledge of the several natural sciences. Having made up his mind to enter the navy, he might at once have presented himself for examination, had it not been for an insufficient acquaintance with some branches of mathematics, in which, owing to the limited instruction given at the college, his information had hitherto remained of a very elementary character. Fortunately, however, a student, who had just left the École Polytechnique, settled at that time in Alais, and the youth was thus enabled rapidly to fill up this gap in his early education.

While Dumas was thus preparing for his naval examination, the political events of 1814-15, and the troubles which in those sad days often stained the department of the Gard with the blood of its citizens, obliged his family to renounce this project and to select a career for the youth which would entail less sacrifice.

Dumas accordingly entered as apprentice at an apothecary's in Alais. This position, in which he pursued his first practical studies, did not afford much opportunity for scientific progress. Besides, the political and religious divisions which disturbed the country and the bloody scenes with which it was afflicted inspired Dumas with a strong desire to quit his native town. This feeling, indeed became so intense that his parents, moved by his evident distress, thought it best to accede to his wishes.

Soon after, in 1816, Dumas travelled on foot from Alais to Geneva, and often in conversation with his friends has he recalled the sad impression which this first journey of his life left upon his mind. Throughout his route the lasting effects of the long wars of the first Empire were visible; and the country was, moreover, devastated by prolonged rains, which had destroyed the crops and thus brought about a famine with all its horrors. Happy changes have long since taken place, and the traveller in the south of France who follows, as the writer of these lines but lately did, the young pedestrian's course along the Rhone, and sees the cheerful peasantry of those provinces, living in well-built houses, will scarcely realise the haggard, emaciated population, badly sheltered in thatched cottages half in ruins, and the dismal aspect of universal misery, which presented themselves to Dumas when traversing those districts more than half a century ago.

At Geneva Dumas found everything to expand his ideas, to stimulate his emulation, and thus to prepare him for his future career. There were lectures on botany by M. de Candolle, on physics by M. Pictet, and on chemistry,

by M. Gaspard de la Rive. He had, besides, the superintendence of a tolerably large laboratory, belonging to the pharmacy of Le Royer, and formerly used for the courses of applied chemistry given by M. Tingry.

The pharmaceutical students who frequently united in botanical excursions during the summer, started the idea of winter meetings for scientific studies. Seeing that Dumas had a laboratory at his disposal, it was suggested that he should give them a course of experimental chemistry. This was his *début* in the professorial career. It was by no means an easy task, for although the laboratory was well provided for all pharmaceutical operations, and even for some chemical experiments of the old school, it possessed none of the modest appliances which a lecturer even at that time required. Most keenly felt was the utter absence of any of the implements necessary for the preparation and collection of gases. But a supply was rapidly improvised. To obtain gas jars, lamp-chimneys were closed with watch glasses, cemented on with wax. An old bronze syringe was turned into an air-pump, and barometer-tubes bent over a flame completed the stock of apparatus. Gradually the laboratory improved. As the ambition of the young professor grew he began to long for a chemical balance. This wish also was satisfied; with the aid of some workmen in a watchmaker's shop an instrument was constructed which enabled him to begin his analytical researches.

Meanwhile, the friendly welcome which had been extended to him on his arrival at Geneva by his relative, M. Bérard, a former associate of Chaptal, began to bear its fruit. Bérard had introduced him to Theodore de Saussure, and to De Candolle, and each of them in his way began to take a warm and lasting interest in him; they encouraged his studies, and assisted him to the best of their powers in his pursuits. It was most likely at the instigation of his new friends that Dumas, reviving his early naval predilections, began seriously to think of, and to prepare for, an exploring expedition to some distant part of the world. A monograph on the Gentianeæ, chiefly written for the purpose of becoming familiar with the language and the ideas of botanical science, was a fruit of these aspirations.

But this was not to be his mission. Biot's great treatise, which for half a century was to remain the standard text-book on physics, had just appeared, and Dumas had found, more especially in the first volume, plenty of subjects directing his attention to the art of experimenting, of making observations, of consulting nature, and of discovering the laws of her phenomena. The *Annales de Chimie* offered him, moreover, splendid models in the papers of Berzelius, Davy, Gay Lussac, and Thenard. At the same time he studied with indefatigable zeal the works of Lavoisier, and the "Statique Chimique" of Berthollet.

He was thus led to work and gradually to make two little discoveries. If neither of them proved to be a great success, they served, at all events, to bring the young experimentalist into friendly relation with one of the leading men of science at Geneva. The author of this sketch has heard from Dumas himself the singular fate of these early discoveries. When analysing various sulphates and other salts of commerce, he had observed that the water they contained was present in definite equivalents. He had not found this recorded anywhere, and had, therefore, taken great pains to establish the accuracy of his observations. When the investigation was finished, he went one morning early to M. de la Rive, and timidly submitted to him the manuscript embodying the results of his inquiry. Whilst glancing over it, M. de la Rive could not conceal his surprise. When he had come to the end he said to the young student, "Is it you, my boy, who have made these experiments?" "Certainly." "And they have taken you a good deal of time to perform?" "Of course they have." "Then I must tell you that you have had the good fortune to meet Berzelius on the same field of research. He has preceded you, but he is older than you, and so you ought not to bear him ill-will on this account." Dumas not a little embarrassed, was unable to utter a single word. It was, in fact, his first interview with M. de la Rive, whose lectures he had attended, but whom he had never personally accosted. But his perplexity was not to last long. With the utmost good nature M. de la Rive put an end to his gloomy reflections, by taking his arm and saying, "Come along and breakfast with me." Before long the conversation had become animated and cheerful. The acquaintance was made, and the kindly feeling of his teacher won by Dumas at this breakfast never subsequently failed him. Indeed, on more than one occasion De la Rive gave him substantial proof of his friendship, especially when somewhat later he permitted him to take part in the experiments which he instituted with the view of verifying, commenting on, and amplifying the ideas of Ampère, and of developing the laws on which they are founded.

But we must not lose sight of the second discovery of the young philosopher. He thought that, knowing the atomic weight of a solid or liquid body and likewise its density, there would be no difficulty in arriving at the volume of the solid or liquid atom. He was thus led to determine, with great accuracy, the density of a number of simple and compound substances the purity of which could be relied upon. Having worked for some time he drew up a paper upon the subject which, in due time, was presented to M. de la Rive. But his friend, though admitting the novelty of the point of view from which the question was treated, did not encourage him to pursue this line of research. Young Dumas was rather disheartened when he left his patron. "The first time," he said to himself, "my experiments were good but they were not new; this time they are new but they do not appear to be good. I shall have to try again."

This inquiry, subsequently continued with Le Royer's son, was nevertheless communicated to the Physical Society of Geneva, and at a later period published in the *Journal de Physique* in Paris, though sadly disfigured by numerous typographical errors. What remains of it is the present method of taking the density of solid bodies, to which but little has been added, and also the principle on which all subsequent inquiries on the atomic and equivalent volumes of bodies are based. It is well known that some twenty years later the subject was taken up again by Hermann Kopp, whose remarkable results proved of great service to chemical philosophy.

Dumas was then eighteen years of age. It was about that time that he had the good fortune to make himself

useful to one of the principal physicians of the town, a circumstance which contributed not a little to advance him in the circles in which he had hitherto lived. One morning Dr. Coindet came in hastily to Le Royer's. "You occupy yourself with chemistry?" he said to Dumas. "To some extent," was the answer. "Then you could tell me whether iodine is present in sponges, and more especially in carbonised sponges?" "I will examine them for you." Having after some days received an affirmative answer, Dr. Coindet no longer hesitated to consider iodine a specific against goitre. Dumas was then asked to give his attention to the subject and to point out the preparations in which iodine might be most conveniently administered. He suggested tincture of iodine, potassic iodide, and iodised potassic iodide. Soon afterwards these new remedies were mentioned in a German journal published at Zurich, and it is in this connection that the name of Dumas is first met with in scientific literature. The same journal gave the formulæ proposed for these remedies, as also their mode of preparation. It need scarcely be mentioned that at that period, so soon after the discovery of iodine by Courtois, none of the iodides were known to the trade, iodine itself being the only commercial article. The discovery of Dr. Coindet produced a great sensation all over the world, and for many years the manufacture of iodine preparations for medical purposes proved a source of wealth and reputation to the pharmacy of Le Royer.

It was at that time that Dr. J. L. Prévost, after an absence of several years, returned to Geneva. He had been residing for a considerable time in Edinburgh and Dublin, devoting himself to comprehensive studies in the several departments of medicine. He had been more particularly engaged in the examination of the physiological effects of digitalis, and was naturally anxious to obtain the active principle of the plant free from all foreign matter accompanying it. He invited Dumas to join him in this inquiry. The problem to be solved consisted in successively removing all that appeared inert so as to concentrate the active constituent, which would ultimately remain in a state of purity. The chemical properties of this principle being unknown, the only means of appreciating the concentration was to observe the effect of the concentrated substance upon animals. This slow and irksome process of elimination did not lead to any result; it is well known that the isolation of digitaline was only much later accomplished. But however unsuccessful, these joint labours gave rise to a far more fruitful collaboration.

Whilst studying together the physiology of Richerand, a work then in great repute, and the memoirs of Magendie, which were beginning to attract increased attention, the two friends asked themselves whether physiology had not to be rebuilt on a broader foundation? What could the analysis of blood mean unless the blood-corpuscles were taken into consideration, or that of milk if the globules of butter were lost sight of? Again, were more than the most imperfect, not to say the crudest notions to be hoped for if any one attempted to analyse the seminal fluid without specially examining into the nature of the spermatozoids? To neglect the formed elements of the solids and liquids constituting the animal economy, which are obviously the true exponents of their character and functions—was this not acting with reference to nature as if an idea of a masterpiece of art could be obtained by reducing it to dust and determining the quantity of carbon, iron, lead, copper, &c., present on the canvas in the oil and colours which the painter had employed? Obviously the study of the materials of the organism had to be taken up again from its very beginning, the microscope of the anatomist and the balance of the chemist mutually assisting and controlling each other. The functions themselves, were they not still shrouded in darkness? What was the mechanism of respiration? Where the seat of the production of animal heat? How was digestion to be explained? How did the organs of secretion perform their work? What was the process of fecundation, where was its principle to be found, and how could its march and progress be traced experimentally? No wonder that these questions, agitated day by day in two young and ardent minds, led to a plan of inquiry embracing nothing more nor less than the whole domain of physiology.

It seemed natural enough to commence with the study of the blood. To define the corpuscles, to measure them, and to compare with each other those existing in the blood of various animals, was the object of a first investigation. A safe process for measuring easily and accurately the corpuscles had to be devised, a new process for the physiological analysis of the blood to be elaborated. This first paper is published in the *Bibliothèque Universelle de Genève;* and in the title Dumas still figures as Elève en Pharmacie. The results arrived at by the young inquirers have for a long time satisfied the wants of science, and if our knowledge of the blood has been considerably expanded by many subsequent observers, amongst whom Andral and Gavarret, Johannes Müller, Magnus, L. Meyer, Brücke, Ludwig, A. Schmidt, Claude Bernard, Stokes, and several others might be quoted, the experiments of Prévost and Dumas have invariably served as a starting-point for their inquiries.

It was about that time that the death of the Princess Charlotte had excited a feeling of sorrow all over Europe. The pathological problem presented by this sad event induced the two experimentalists to resume the study of the transfusion of blood. They thought that in the presence of the calamity which threatened the royal house of England, medical art had been deficient in initiative, that in this case the transfusion of blood should have been tried, and that it might possibly have saved a young and hopeful life. Numerous and varied experiments carried out by them supplied new proofs of the possibility of rekindling, as it were, the life of an animal reduced to extremity by prolonged hæmorrhage, by the transfusion of the blood of another animal of the same species. But if the blood was supplied by an animal of another species, death invariably ensued. Still even the surprising effects observed in the former case but rarely led to ultimate recovery; and Prévost and Dumas concluded that so long as the nature of blood is but imperfectly understood, transfusion must be looked upon as an extremely dangerous operation, which should not, except in hopeless cases, be applied to man. It is well known that, even at the present time, the opinions of medical men on transfusion remain divided.

Another important result, elicited by the experiments of Prévost and Dumas, was the demonstration of the presence of urea in the blood of animals, the kidneys of which had been removed. Since the imperfection of the analytical methods of that period did not permit them to recognise the presence of urea in normal blood, they drew from their experiments, which proved its presence in the blood of animals deprived of their kidneys, the legitimate inference that these organs do not produce urea, but only separate it, in order to eliminate it from the blood. It is but right to insist upon this point. If we were to limit ourselves to saying that the joint investigators had discovered urea in the blood of nephrotomised animals we should state a fact, but not explain their mode of working. Is it a function of the organs of secretion to generate the products which they separate from blood or lymph, or have they merely to eliminate the products already formed by a general action affecting the vitality of the whole system? To answer this question it was necessary to remove the organ of secretion, to keep the animal alive during a few days, and to be able to recognise, by unmistakable reactions, the presence of the characteristic constituents of the secreted liquid in the blood. It was possible, for instance, to extirpate the mammæ of a female animal in full lactation, but how were the constituents of the milk to be indubitably traced in the blood? The removal of the liver was not practicable. The extirpation of the kidneys, on the other hand, offered every chance of success. By operating with especial care it was to be hoped that the animal would live for a couple of days. If the non-eliminated urea continued to be produced within the system the characteristic properties of that body must reveal its presence in the blood. It was thus that the problem was put, and it was thus that it was answered.

The experiments of Prévost and Dumas have been repeated by the most distinguished observers, amongst them by Gmelin and Tiedemann, as well as by Mitscherlich, and the conclusions to which they led are therefore generally adopted by physiologists. We should not, however, leave it unmentioned, that, during the last few years, some dissenting voices have been heard. We refer to the experiments of Zalesky, who believes that he has proved urea to be generated by the kidneys. These experiments have not, however, invariably succeeded in the hands of other observers, so that still farther evidence of very considerable weight must be adduced before this view can be adopted; and, even in case of its confirmation, secretion of urea produced in blood and tissues may still be found to be the principal function of the kidneys, though not the only one, as Prévost and Dumas had inferred from their experiments on the blood of animals after extirpation of that organ.

It may not, perhaps, be without interest to remind the reader that in those days, already far behind us, vivisection was not recognised, as it is now, as a necessity for scientific progress, and that, of all continental cities, Geneva certainly offered the most limited facilities for carrying it out, and the smallest chance of escaping public reprobation. What endless precautions had the two friends to take to deceive the good citizens of Geneva! The chief of the guard had given them permission to use one of the casemates of the fortifications, which had access from the promenade of Bel-Air. At two or three o'clock in the morning they used to descend to this deserted quarter of the town, provided with the necessary instruments, and holding in their hands a lantern, which gave them the appearance of a patrol, so that even when seen they attracted no further notice. The whinings of the animal were lost in the depth of the walls, and, the operation having been performed, and the dressing applied to the wound, the experimentalists had no further difficulty in taking the poor creature home without having troubled any one.

There were still other problems that attracted their attention. What was the secret of fecundation? What part in this phenomenon was to be attributed to the male and what to the female? Long and patient studies on the propagation chiefly of the batrachians, which may be looked upon as a continuation of the earlier researches of Spallanzani, enabled them to demonstrate that in the generative organs of all males spermatozoids are present, differing in form and dimensions, but all exhibiting the well-known rapidity of movement. Nothing of the kind could be observed with females. The seminal fluid deprived of spermatozoids had no longer any fecundating power. Thus for the first time it was proved that the formed elements exercise a preponderating influence in certain of the most obscure physiological phenomena, officiating as excitatory agents charged with the transmission of vital energy. The ovum submitted to the influence of the spermatozoids was fecundated and soon presented the phenomena of segmentation, which is to-day considered as the sure and general indication of the first stage of the development of the embryo, but which, strangely enough, had scarcely been studied up to that time. The phenomenon, it is true, had not altogether escaped the observations of Swammerdam and Spallanzani, who noticed it in the ovum, the former in that of the frog, the latter in that of the toad, but both failed to appreciate its true character, so that modern physiologists are unanimous in recognising Prévost and Dumas as the discoverers of the phenomenon of segmentation in the ovum of the batrachians. At the same time (in 1824) these investigators observed that at a certain stage of fecundation there escapes from the ovary of the mammalia a limpid almost microscopic vesicle which enters the Fallopian tube, and proceeds to the uterus, where, when impregnated by the spermatozoids of the male, it is fixed, and increasing in size and development gives rise to the fœtus. Prévost and Dumas must thus be looked upon as the precursors of C. E. Baer, whose classical researches on the genesis of the ovum in the mammalia and in man appeared in 1827.

Having had to examine the labours of Spallanzani whilst engaged in their researches on fecundation, Prévost and Dumas were struck by the inestimable value of the results obtained by the Italian observer and by the astonishing sagacity which he displayed in conceiving and executing his delicate experiments. They were of the opinion that Spallanzani, obviously in advance of his century, had not been sufficiently appreciated by his contemporaries. In fact Dumas has never ceased to look upon Spallanzani as the originator of experimental physiology. According to Prévost and Dumas, the exactitude of his statements about artificial digestion

is not less proved than that of his observations on fecundation. They had taken the trouble of repeating all the experiments made by Spallanzani for the purpose of collecting the gastric juice, and of demonstrating its solvent power for solid food, and more especially for meat.

It must not be forgotten that at that period already very far from our own time, but few could persuade themselves that physiological facts elicited by the observation of animals were available also for the physiology of man. It is with difficulty that we realise at present the views then generally prevalent among medical men, who obstinately refused to believe that a truth established for frogs and guinea pigs was likely to be a truth holding good also for man. Prévost and Dumas, on the contrary, thought with Spallanzani, that comparative anatomy and physiology offered unexpected resources for the solution of the problem of life, by searching where it presented itself in its simplest form. They were also of opinion that if man is distinguished from animals by his soul, his body, greatly resembling theirs, obeys the same laws. They did not, therefore, hesitate to embark in comparative physiology, and to seek at the lowest end of the animal scale the answer which creatures of a higher organisation, and more especially man, refused to give.

Simultaneously with their researches on blood and fecundation, Prévost and Dumas published several other physiological investigations not immediately connected with the main subjects of their studies. No task appeared too arduous, no question too difficult for their spirit of work, for their delight in inquiry. The ovum and the organs of secretion of frogs, successively engaged their attention. They also studied the phenomena accompanying the contraction of muscular fibre. When investigating the distribution of the motor nerves in the striated muscles, they had most happily selected the almost transparent muscles of the abdomen of the frog and were thus enabled to trace the ultimate ramification of the nerves without dissecting the muscle. Having established, as they thought, the fact of the nerves not terminating but forming a sort of loop, both branches of which they assumed to be in connection with the brain, and having observed, moreover, that during contraction the primary fibres of the muscle bend in a zigzag-like manner, Prévost and Dumas were led to a most ingenuous interpretation of the phenomenon founded on Ampère's then recent discovery of the law of action between two electric currents which, when parallel and flowing in the same direction, attract each other. They suggested that such electric currents might be assumed to circulate within the muscular fibres, when the mutual attraction exerted upon each other by the loops would be sufficient to account for muscular contraction. Seductive as this hypothesis appeared in the light of the knowledge of that period, it has not stood the test of time. The conception of the identity of the nervous principle and electricity, widely spread in those days, has long since been entirely abandoned. Still Prévost and Dumas's notion of the loop-like termination of the motor nerves and of the zigzag-like bending of the primary muscular fibres during contraction was generally believed for nearly a quarter of a century. The improved means of observation at the disposal of modern physiology have, however, gradually thrown a new light upon this subject which, more especially since the remarkable discoveries of Rudolph Wagner on the one hand, and of Richard Owen and Eduard Weber on the other, has acquired a perfectly different aspect.

Lastly, Prévost and Dumas's suggestion as to the treatment of stone by electricity should not be left unnoticed. Their experiments showed that the current of a powerful battery is capable of destroying and dissolving the phosphatic calculi of the bladder, without its mucous membrane being materially affected. Although, at a subsequent period, these researches were continued and materially enlarged by the late Dr. Bence Jones, the author of this sketch has not learnt whether the treatment indicated by these remarkable results has been successfully applied in surgery.

Researches on animal physics, embracing so great a variety of subjects, could not have been undertaken and carried out without a profound knowledge of comparative anatomy on the one hand, and of the methods of physics and chemistry on the other. It need scarcely be mentioned that in their happy collaboration, the anatomical operations were performed by Prévost, while the experiments involving the use of physical and chemical apparatus were Dumas's share in the work. The delicate nature of these experiments often compelled him to alter existing instruments or to invent new ones, so that these early physiological labours in Geneva afforded him ample opportunities of developing and cultivating those inventive faculties which were to be exercised with such signal success in his subsequent researches.

The joint labours with Prévost did not prevent Dumas from engaging simultaneously in independent investigations. Biot, in the first volume of his celebrated treatise on physics, had given numerous examples of the mode of representing continuous phenomena, such as the expansion of liquids, by formulæ of interpolation, which may be happily replaced by curves. As examples, Biot had chosen Deluc's experiments on the expansion of fixed and volatile oils; but these experiments had been made with the oils supplied by commerce, *i.e.*, with mixtures, the examination of which was not likely to lead to the recognition of a law. They showed that expansion was a continuous phenomenon; nothing more.

Dumas conceived the idea of resuming this inquiry with well-defined pure substances. He expected that the study of several compounds analogous in composition, and therefore comparable with each other, would lead to interesting results. The class of bodies selected for experiment was that of the compound ethers. A good many preliminary operations were required for this inquiry. It was necessary that the substances to be worked upon should be submitted to analysis, in order to insure their purity; the dilatometers to be used had to be graduated. Great obstacles, indeed, were met with on the very threshhold of the inquiry. It was found by no means easy to procure the materials necessary for starting the experiments. The only ethers then readily accessible were those of nitric, acetic, benzoic, and oxalic acids, for the fuming chlorhydric ether, likewise known at that time, undoubtedly belonged to a perfectly different type. The four ethers just mentioned presented, however, all sorts of difficulties. Even now the preparation of absolutely pure acetic ether is by no means an easy task;

what was called nitric ether was found in reality to be the ether of nitrous acid; the formula of benzoic acid not being accurately known, that of its ether was *à fortiori* doubtful; lastly, a more minute examination of oxalic ether proved that its constitution differed essentially from that of the ethers previously mentioned. Moreover, the analytical results were not in accordance with the ideas then accepted. Chemists at that time were in the habit of considering compound ethers of oxacids to be generated by the union of alcohol with the so-called anhydrous acids, whilst the analyses made by Dumas pointed rather to ether as the proximate constituent which enters into combination with these acids. Owing to the difficulty of preparing the ethers in a state of purity, to the uncertainty of the results obtained in their analysis, which was then performed by the volumetrical method, and to the doubts still entertained even as to the composition of the acids present in them, the original aim of the inquiry was more and more lost sight of. Dumas felt that the expansion experiments had to be postponed, until the nature of the compound ethers should have been more satisfactorily made out. He resolved to wait for more favourable circumstances in order to reconstruct this work on a broader foundation, communicating to the Société de Physique for the present only the first results of his experiments, in which he had been engaged for the better part of the years 1819 and 1820, and insisting more especially on the probability of these bodies being compounds of ether and not of alcohol with anhydrous acids. This suggestion does not appear to have attracted much notice at the time; it was not until a later period that the question began to engross the attention of chemists, when Dumas had been enabled to carry out his intention of submitting this interesting class of compounds to an elaborate investigation, which was published in 1827, and to which we shall have to refer hereafter.

If from our present standpoint we glance back at these early labours in the domain of organic chemistry, we cannot but feel deeply impressed by the dauntless courage with which the pioneers of that period penetrated into regions utterly unknown, perseveringly opening the ground, sowing broadcast on the virgin soil, and thus preparing those splendid harvests of which the present generation are the grateful reapers.

At this period, *i.e.*, in 1822, Dumas might have settled at Geneva, and many circumstances led him to think seriously of doing so. An incident, however, which happened at that time, and which at first sight seemed in no way likely to influence a well-matured plan of life, induced him within a few days to change his mind. He made the acquaintance of a man, amongst whose varied gifts the fascinating sway he exercised over youthful minds was not the least. Let me try to give the story in the very words in which I heard it from Dumas's mouth. "One day," he said, "when I was in my study completing some drawings at the microscope, and, it must be added, rather negligently attired, in order to enable me to move more freely, some one mounted the stairs, stopped on my landing, and gently knocked at the door. 'Come in,' said I, without looking up from my work. On turning round I was surprised to find myself face to face with a gentleman, in a bright blue coat with metal buttons, a white waistcoat, nankeen breeches, and top boots. This costume, which might have been the fashion under the Directory, was then quite out of date. The wearer of it, his head somewhat bent, his eyes deep-set but keen, advanced with a pleasant smile, saying, 'Monsieur Dumas?' 'The same, sir; but excuse me.' 'Don't disturb yourself. I am M. de Humboldt, and did not wish to pass through Geneva without having had the pleasure of seeing you.' Throwing on my coat I hastily reiterated my apologies. I had only one chair. My visitor was pleased to accept it, whilst I resumed my elevated perch on the drawing stool. Baron Humboldt had read the papers published by M. Prévost and myself on blood, which had just appeared in the *Bibliothèque Universelle* and was anxious to see the preparations I had by me. His wish was soon gratified. 'I am going to the Congress at Verona,' said he, 'and I intend to spend some days at Geneva, to see old friends and to make new ones, and more especially to become acquainted with young people who are beginning their career. Will you act as my cicerone? I warn you, however, that my rambles begin early and end late. Now, could you be at my disposal, say, from six in the morning till midnight?' This proposal, which was of course accepted with alacrity, proved to me a source of unexpected pleasure. Baron Humboldt was fond of talking; he passed from one subject to another without stopping. He obviously liked being listened to, and there was no fear of his being interrupted by a young man who for the first time heard Laplace, Berthollet, Gay-Lussac, Arago, Thenard, Cuvier, and many others of the Parisian celebrities, spoken of with familiarity. I listened with a strange delight; a new horizon began to dawn upon me. Save the time devoted to some visits I was allowed to remain the whole day with Humboldt, who darted from point to point over the vast range of his recollections, whilst I endeavoured to keep pace with the uninterrupted flow of his narrative. Sometimes the mountain scenery would remind him of the Cordilleras, though it must be confessed he did not think much even of Mont Blanc. Sometimes he turned to science, and then astronomy and physics, chemistry and the natural history branches would, in rapid succession, come in for their share in the dialogue, or rather monologue, which, spoken in a low, somewhat monotonous tone, would have scarcely appeared impressive, had it not been for some waggish pleasantry which now and then escaped, as it were, involuntarily. But, at any rate, if his voice failed to be effective, the glance of his eye was sufficient to rivet his hearers' attention.

"At the end of a few days Baron Humboldt left Geneva. After his departure the town seemed empty to me. I felt as if spell-bound. The memorable hours I had spent with that irresistible enchanter had opened a new world to my mind. I had been more especially impressed with what he had told me of Parisian life, of the happy collaboration of men of science, and of the unlimited facilities which the French capital offered to young men wishing to devote themselves to scientific pursuits. I began to think that Paris was the only place where, under the auspices of the leaders of physical and chemical science, with whom, I had no doubt, I should soon become acquainted, I might hope to find the advice

and assistance which would enable me to carry out the labours over which I had been pondering for some time. My mind was soon made up—'I must go to Paris.'"

The interest with which Dumas recounts this incident, which brought his stay in Geneva to a somewhat sudden termination, leaves no doubt as to the deep impression which the short intercourse with Alexander von Humboldt had made upon his mind. We have here, indeed, one more illustration of the peculiar predilection of the German *savant* for youthful inquirers, of the sagacity with which he discovered rising talent, and of the irresistible fascination which no one was able to withstand. It is well known what a powerful patron he proved to Liebig, who has left us a charming account of his first acquaintance with the famous traveller; and it is certainly worthy of note that two inquirers, whose labours subsequently carried them to the head of chemical science, should each have been befriended on the very threshold of his career by the same master mind, so that in later years they never ceased to acknowledge in affectionate terms the debt of gratitude which they owed to Alexander von Humboldt.

Dumas's removal to Paris, which took place in 1823, brought the physiological labours in which he had been engaged along with Prévost to a conclusion. It is true the Genevese physiologist subsequently followed his friend to the French metropolis, where he remained for some time, but it was chiefly for the purpose of finishing some of the researches which had been left incomplete and of preparing their papers for the press. Prévost's stay in Paris was a comparatively short one; moreover, the two friends were mostly engaged with their own affairs—Prévost with extending his acquaintance among the eminent physiologists of the day, Dumas devoting himself more and more to the investigation of the purely chemical questions which he had been cogitating even at Geneva. At all events, no new plans were formed for further joint inquiries in physiology, the execution of which would have been greatly impeded by Prévost's return to his native town, where he ultimately established himself.

Though the separation from a friend, with whom he had been in daily intercourse for so many years, must have been deeply felt by the young *savant*, who had now to steer his course alone, he had the good fortune to become acquainted with three young men of about his own age, with whom he soon entered into friendly alliance. These were Victor Audouin, the zoologist, well-known even at that time, Adolphe Brongniart, who had already published several important botanical papers, and Henri Milne Edwards, who had just terminated his medical studies and was working for his degree. The friendship of these three men matured by daily intercourse, and subsequently strengthened, if possible, by family ties, has ever been looked upon by Dumas as one of the most important acquisitions of his life, not only proving to him an inexhaustible source of the purest pleasures, but likewise materially assisting in shaping that successful career which has made the name of Dumas a household word in the mouths of chemists. And of the hearty sincerity with which these feelings were returned, we have a charming testimony in the eloquent terms in which, a third of a century later (1857), Milne Edwards dedicated his celebrated lectures on the physiology and comparative anatomy of man and animals to his friend Dumas as a tribute of his affectionate regard for the man and his admiration of the investigator.

If a legitimate desire to become acquainted with the leading men of science of that day was one of the principal motives in determining Dumas to leave Geneva, his wishes were gratified far beyond his most sanguine expectations. Nothing could have surpassed the kindness with which the young aspirant was received by the very men to whom he had hitherto been looking up with mingled feelings of reverence and awe. As an illustration of the sympathetic interest which the most illustrious *savants* of the period accorded to the labours of their youthful fellow-workers in the field of science, Dumas is fond of describing his own *début* in the Academy of Sciences. Having read a joint paper of his and Prévost's on muscular contraction, he had modestly retired into the embrasure of a window (as would become his age), when a member of the Academy—a veteran with white hair and a most dignified countenance—rose on the other side of the table and walked up to him. "Monsieur Dumas, will you do me the honour of dining with me on Wednesday next?" he asked the astonished young chemist in a most formal manner. Nothing could be more natural than to accept so kind an invitation. After an exchange of a few polite words Dumas's new friend gravely retired to his place, receiving everywhere unequivocal marks of the greatest respect. "With whom am I to dine?" asked Dumas of one of his neighbours. "Do not you know M. de Laplace?" was the answer. And not only did Dumas dine with Laplace, but he learnt with lively interest that the illustrious astronomer had retained a sort of passion for physiological inquiries ever since he had jointly worked with Lavoisier on animal heat and respiration. A regular intercourse of a most friendly character was the consequence of this somewhat abrupt invitation, which continued with Madame la Marquise de Laplace, who for many years survived her husband; and it was obviously in the society of Laplace, who never ceased to deplore the untimely and cruel death of his noble fellow-worker, that Dumas was first impressed with those feelings of affectionate reverence, bordering on worship, with which he has ever since regarded the name of Lavoisier.

Nor should it be left unmentioned that many years later a striking proof was given of the friendship accorded by Laplace to young Dumas. When the family, then represented by his son, the General of Artillery, and his granddaughter, Madame la Marquise de Colbert, decided to publish at their own expense, the complete works of the illustrious astronomer, they were anxious that the old friend of the house should be entrusted with the task, and accordingly the splendid edition of Laplace's works, in twelve quarto volumes, of which two appeared in the course of 1878, is published under the auspices of Dumas and Bertrand.

And this kindly feeling of good fellowship towards youthful workers in the field of inquiry of which Laplace had given so bright an example, was shown by nearly all his contemporaries. Berthollet, Vauquelin, Gay-Lussac, Thenard, Alexandre Brongniart, Cuvier, Geoffroy St.

Hilaire, Arago, Ampère, Poisson, all have given striking proofs of their desire to smooth the path of young investigators, and thus to promote the advance of science.

The place of Répétiteur de Chimie to Thenard's course of lectures in the École Polytechnique having become vacant at that time, Arago proposed Dumas for the office, who was elected by the council of the School before he had become aware that he was a candidate. There was at that period in Paris an establishment for evening lectures on literature and science, resembling in a measure the Royal Institution of Albemarle Street, though the literary element predominated. This institution, originally called Lyceum, but better known by its later name of Athenæum, was founded and maintained by public subscription; it occupied a mansion in the Rue Valois, in the neighbourhood of the Palais Royal. It was there that La Harpe's celebrated course on literature (published in 1799) had been given. At the time of which we speak Magendie lectured on physiology, Mignet on history. The chair of chemistry at the Athenæum, hitherto occupied by Robiquet, had become vacant by the resignation of that chemist, and Ampère succeeded in procuring the appointment for Dumas without having previously spoken to him on the subject. From this moment, owing to the influence of his two illustrious protectors, the study of physiological questions receded still further into the background, whilst his full energy was directed towards the solution of chemical problems.

Those who had known the chemical laboratories of the previous period established in a large way, and permitting the execution of the most complicated operations on an almost manufacturing scale, would have scarcely realised what miserable corners, denominated by the dignified name of laboratory, the chemical Répétiteur at the École Polytechnique had to put up with, when Dumas came into office. The famous laboratories which had witnessed the grand experiments on potassium and sodium, and the researches published in the two volumes of Gay-Lussac and Thenard, were no longer in existence. The great battery had wandered into the lumber-room. All the Répétiteur had at his disposal was a sort of kitchen for the preparation of the lectures, and a little room without a fire-place, furnished with cupboards for the specimens. Indeed, Dumas was sorely disappointed on taking possession of his magnificent apartment. There was neither balance nor barometer, no thermometers, no graduated tubes and vessels, in fact, no instrument of precision for research. The whole stock of the laboratory consisted in the apparatus and preparations used for the manipulations and demonstrations in a course of general chemistry.

At that period it was by no means an easy task to furnish a laboratory with the means of working, and more especially to procure the instruments of precision required for delicate experiments. Philosophical instrument-makers were scarcely in existence. This important industry, which has since been so wonderfully developed with the growth of science, had still to be created. With the exception of Fortin, who was still alive, and devoted himself to young experimentalists with the same ardour with which in his youth he had assisted Lavoisier, there were no makers who were not persuaded that apparatus was for show and not for use. Unmistakably, the unlimited resources of the French metropolis, which from a distance presented themselves in such a seductive light, had in reality dwindled down into utter insignificance. There was, indeed, no help for our young friend but to trust again to those inventive faculties which had carried him through similar difficulties at Geneva. Still, several years elapsed before he succeeded in mounting his laboratory on a decent scale, so as to be prepared for actual work.

But it was not only the want of a well-appointed laboratory which prevented him from engaging much in scientific researches during the first years of his stay in Paris. His lectures at the Athenæum required a great deal of preparation; he was, moreover, in his capacity as assistant to Thenard's course at the École Polytechnique, assiduously practising the art of experimenting in public, in which he soon attained the highest degree of proficiency. At the same time he founded (in 1824), with his friends, Audouin and Brongniart, the *Annales des Sciences Naturelles*, and also began to collect the materials necessary for the publication of his grand "Traité de Chimie appliquée aux Arts," the first volume of which appeared in 1828.

But if this period was for Dumas one of incessant labour, and often of the most strenuous efforts, it also carried him to the sunny height of life by realising the most ardent of his aspirations. He succeeded in gaining the affections of the lady who has been his faithful companion for so many years. For some time Dumas had been intimate with the family of Alexandre Brongniart, the father of his friend Adolphe. It was not long before he became betrothed to Mdlle. Herminie Brongniart, the eldest daughter of the illustrious geologist. It was on February 18, 1826, that the matrimonial alliance was concluded which has been for more than half a century—may it yet continue for many a year!—a source of the purest happiness for both consorts. Of what Mdme. Dumas has been to her husband as an ever-cheerful partner of his lot, as a devoted mother of their son and daughter, as a counsellor and helpmate during the varied stages of his active life, and as a genius of consolation during the vicissitudes which were not wanting, of all this no one can form the slightest idea, unless he has been a fortunate sharer in that noble hospitality which under her auspices has ever made the house of Dumas a centre of attraction for society in Paris.

At the very commencement of his labours in the cause of organic chemistry Dumas had found himself face to face with a powerful rival in Germany, who, setting out by a curious coincidence from the same starting-point, the study of pharmacy, had entered the lists without passing through the physiological and natural history stages of his competitor. Liebig and Dumas have had, indeed, some strange encounters on the field of science. Still these collisions, arising chiefly from their having simultaneously engaged in the same inquiries, did not surprise them. They knew very well that at a moment when organic chemistry had, as it were, to be reconstructed on a new basis, it was far less important to discover new bodies than to assign their place to those already known. There was no lack of phenomena observed but not explained, and it was therefore but natural that many

of the problems to be solved should simultaneously rivet the attention of several inquirers.

These encounters, to which we may have to refer hereafter, were occasionally rather violent, as might have been expected when two young and fiery champions, each persuaded of the justice of his views, were rushing at each other. Once or twice perhaps in the heat of battle an unguarded word might have sounded like personal provocation, but, however fierce the aggression, the combatants never forgot that they were both fighting under the banner of truth, and the contest having been decided, the antagonists invariably separated with increased regard for each other. In reviving the memory of these struggles it is pleasant to listen to what, in later years, the two opponents had to say upon the subject. Referring in his commemoration speech on Pelouze to their labours in organic chemistry, Dumas said: "Into this as yet uncultivated domain we had plunged, Liebig and I, with most lively ardour. The number of organic substances, nowadays immense, was even then very considerable. Their study, however, if we except the group of bodies selected by Chevreul for his researches, had not as yet elicited results of any great importance. The nature of most compounds was unknown; their differences, their analogies, their connections had still to be unveiled.

"To find our way through these unexplored territories, we had neither compass nor guides, neither method nor laws. Each of us had been led to form ideas and to elaborate views peculiar to himself, which he defended with warmth and even with passion, but without any feeling of envy or jealousy. The discoveries to be made appeared to us without limit, and each was satisfied with his harvest. What we both had at heart was to stake the ground and to open roads, nor have I any doubt that in reading my papers Liebig felt the same pleasure which the perusal of his afforded me. If a new step had been taken, it was of little moment whether it had been made by the one or by the other, since it served us both on the oad to truth."

And these sentiments of affectionate regard were warmly returned by Liebig, who expressed them on several occasions, and never more emphatically than when dedicating to Dumas a German edition of his "Familiar Letters on Chemistry." It is delightful to read the note which Liebig on this occasion addressed to his former antagonist:—

"MY DEAR DUMAS,—It was by a strange coincidence that for more than a quarter of a century our labours in the cause of the science, to which our lives have been devoted, were prosecuted in the same direction. If the roads by which we endeavoured to attain the goal were often different, in the proximity of that goal we always met in order to shake hands with each other.

"Not only your country, but the whole scientific world, acknowledges the range, the depth, and the importance of your researches and discoveries, but no one knows better than myself the obstacles which your genius had to surmount in order to achieve those inestimable conquests which, in a measure, constitute the foundation of modern science. Though contending with difficulties of every kind, you never descended into the arena without leaving it as conqueror.

"Permit me, in deep-felt recognition of the services which you have rendered to science and to mankind at large, to dedicate to you this little work, in which I have ventured to sketch for an enlarged circle of readers the onward movement of scientific and applied chemistry, to which you have so much contributed. Your approbation would be the highest reward I could possibly hope for.

"Giessen, June, 1851 LIEBIG"

Nor was Liebig's admiration limited to Dumas, the chemical inquirer; he no less appreciated and loved the man. Of this he has given striking proof in his charming letters to Wöhler, some of which were lately published. In one of them Liebig describes at some length a delightful meeting with Dumas under the hospitable roof of their common friend, M. Kuhlmann, at Lille, concluding with the words, "In truth he is a grand character."

But we must return to Dumas's early labours in the field of experimental investigation. They were by no means exclusively devoted to organic chemistry; indeed, one of his first researches, which riveted at once the eyes of the scientific world upon the young French chemist, was of a much larger scope. We allude to the classical paper "On some Points of the Atomic Theory," which was published in the *Annales de Chimie et de Physique* for 1826, and in which the author soars to the very heights of chemical philosophy. Whoever to-day, after a lapse of fifty-three years, peruses this admirable memoir, which aims at the solution of old problems by new methods, cannot but gratefully acknowledge that a good deal of what has long since become common property, is rooted in its substance; but he will at the same time be astonished to perceive that many of our modern views, which we are in the habit of considering as the acquirement of the last few decades, had already found expression in this paper.

It was the uncertainty of the results of former inquiries into the atomic weights of the elements which induced Dumas to enter upon the investigation, and, for the purpose of reaching the goal, to steer a course not hitherto taken. Indeed, we meet on this occasion for the first time with the practice of a method of inquiry, without which researches in chemistry appear to us nowadays well nigh impossible. In glancing back at the results of this memoir in the light of our present views we perceive at once what a start the French chemist had gained on his contemporaries. "I am engaged in a series of experiments," he says, "intended to fix the atomic weights of a considerable number of bodies, by determining their density in the state of gas or vapour. There remains in this case but one hypothesis to be made, which is accepted by all physicists. It consists in supposing that in all elastic fluids observed under the same conditions, the molecules are placed at equal distances, *i.e.*, that they are present in them in equal numbers.

"An immediate consequence of this mode of looking at the question has already been the subject of a learned discussion on the part of Ampère"—and Avogadro, as the author subsequently adds—"to which, however, chemists, with the exception perhaps of M. Gay-Lussac, appear to have given as yet but little attention. It consists in the necessity of considering the molecules of the simple gases as capable of a further division, a division occurring in the moment of combination and varying with the nature of the compound."

It is obvious that the author opens his inquiry with the very conceptions which form the basis of our present views in chemical philosophy; and it is only to

be wondered at that the happy enlistment of the celebrated physicists' ideas into the service of chemistry, which we owe to Dumas's initiatory sagacity, should, for more than a quarter of a century, almost have fallen into oblivion.

Having premised in lucid terms the general scope of his inquiry, Dumas proceeds to describe the several modifications of the well-known method of taking vapour-densities, with which he has endowed science, and which went forth from his hands in such a state of consummate perfection, that there has scarcely been room left for subsequent emendation. Looking at its extreme simplicity, he does not hesitate to predict its general adoption in chemical laboratories, and never has any prediction been more fully realised. The number of determinations made by this method is legion. Is there a chemist who, in the course of his researches, has not repeatedly employed it? Cahours, in his great investigation on the increase of the vapour-density of acetic acid at temperatures but little above its boiling-point, made use of Dumas's method exclusively. The immense advantage offered by this process, when compared with that of Gay-Lussac, consists in the wide range of temperatures which it commands, a range which is still further extended by the substitution of porcelain for glass, suggested by St. Claire-Deville and Troost, when extreme temperatures are to be attained.

Of the numerous results obtained by Dumas himself, we can quote only some of those which served him in his atomic speculations, and for the acquisition of which the method had been elaborated. In determining the vapour-densities of the chlorides of phosphorus, arsenic, boron, tin, and silicium, and of some of the fluorides of these elements, he arrived at values which have not since been modified. Also the atomic weights of phosphorus, arsenic, and boron, which he deduced from those values, by considering as atoms the quantities of these elements contained in *two* volumes of their chlorine or fluorine compounds, are those we recognise at present. And, although seduced perhaps by the apparently greater simplicity of the ratios, he hesitated to pursue his own ideas to their ultimate consequences, and adopted as the atomic weights of tin and silicium the quantities of these elements present in *one* instead of two volumes of their compounds, arriving in this manner at half the values recognised at present, the immediate result of his experiments was, nevertheless, a radical change in the views chemists had hitherto held regarding the constitution of one of the most important compounds occurring in nature, of silicic acid, and consequently, of the countless number of minerals, of which silicic acid is a constituent. Now it happened that only a short time previously Berzelius had published his elaborate memoir on a classification of the silicates, founded on the assumption that the atom of silicium was three-quarters of our present weight, and the corollary that the molecule of silicic acid contained three atoms of oxygen. By adopting the atomic weight of silicium at which Dumas had arrived by determining the vapour density of the chloride and fluoride, silicic acid could no longer be regarded as a trioxide. Nor did Dumas hesitate to pronounce it to be a monoxide, which in the notation now employed means a binoxide. But if such was the case the memoir on the classification of the silicates by Berzelius had lost its importance as a sort of legislative enactment, in which even the form of expression claims inviolability. Of this fact the illustrious Swedish philospher was painfully aware, and he therefore made the most strenuous efforts to defend the old formula of silicic acid. In a letter addressed to the young French chemist he advises him to be more careful in the interpretation of his experiments, the correctness of which he frankly acknowledges, and warns him not to be so carried away by the isolated evidence of a single experiment as to doubt the aggregate evidence of a great many others. The letter is couched in very conciliatory terms; it is not difficult, however, to read between the lines how deeply the writer is interested in the fate of his formula of silicic acid. But the progress of science does not shrink from putting her iron heel upon the predilections even of her most ardent devotees. The new mode of looking at the constitution of silicic acid slowly but surely gained ground, and it is now so firmly rooted in our convictions, that the younger generation of chemists will scarcely understand the pertinacity with which this innovation was resisted.

It is only right to add, however, that Berzelius was not the man to offer an obstinate resistance to the inexorable logic of experiment, or to cherish any angry feeling against those by whom even his most cherished notions had been upset; nor, on the other hand, did Dumas in any way resent the criticisms—occasionally somewhat personal—to which the Swedish chemist had then, as well as on several other occasions, given vent; and when Berzelius came to Paris in 1839 the intercourse of the two great chemists was of the most friendly character.

Although Dumas's paper, "On some Points of the Atomic Theory," produced a powerful impression at the time, and has had lasting effects on the development of chemical philosophy, the present reader is nevertheless astonished that Avogadro's hypothesis of the constitution of matter which had served him as a starting point, and had gained considerable support by his researches, did not at that time take permanent root in the conception of chemists, and that nearly three decades had still to elapse before this hypothesis became the generally received basis for the consideration of chemical phenomena. A variety of circumstances certainly have concurrently produced this retardation. Still we cannot refrain from asking, why did Dumas shrink from reaping the full harvest of this fruitful hypothesis? why did he not, to mention only one point, express all compounds by equivolumic formulæ, which would have thus become the representatives of their molecules? Again, we are surprised that the unequivocal distinction of physically smallest particles and chemically smallest particles, traceable throughout the memoir, is not sufficiently marked by special designations, so as to assist the reader in grasping the two conceptions in their contrast. There can be no doubt that the happy unanimity with which the present leaders of chemistry by whom Avogadro's hypothesis is fully recognised, have agreed to designate the former as molecules, the latter as atoms, has greatly facilitated the discussion of the question. How thoroughly the conviction of the necessity of this distinction had taken possession of Dumas's mind, we perceive even more clearly from the introduction to his treatise on Chemistry applied to the Arts, published

about two years later, in 1828, where for the first time he makes uses of the often quoted example illustrating the question by the formation of chlorhydric acid. If 1 litre of hydrogen assumed to consist of 1000 atoms, and 1 litre of chlorine, consisting on the same assumption of 1000 atoms, produce 2 litres of chlorhydric acid, obviously containing 2000 atoms, are we not, with Dumas, compelled to admit the necessity of a further subdivision of elementary atoms? I need not point out that every professor, nowadays, uses this illustration when he wishes to explain to his students the difference between elementary atoms and elementary molecules.

Now, if notwithstanding this unmistakable contradistinction of physical and chemical atoms, Dumas did not in 1826 arrive exactly at the conception which, after the lapse of half a century, appears to us to be the logical consequence of his inquiry, we must not forget that chemists were not then in possession of the host of facts which the labours of several generations of workers have accumulated since that time. Again, the peculiar nature of Dumas's genius must not be lost sight of. In his penetrating mind the power of ardent speculation is so happily balanced by sober, conscious subordination to the irrefutable evidence of experiment that he most resolutely resists yielding to any temptation which might shift him from the solid ground of observation. Indeed, so deeply rooted in his mind is the conviction of the advancement of chemistry being best promoted by exclusive reliance on facts experimentally established, that at a later period, in his lectures on chemical philosophy, he actually expresses the wish that the word atom might be cancelled from chemical language, inasmuch as he considers the chemist using this term no longer within the precincts of experience. Is it to be wondered at that an investigator with such principles for his rule of conduct should have shrunk from allowing himself, by speculating upon Avogadro's hypothesis, to be carried to inferences which did not at the time appear to him sufficiently supported by observed facts, and that his hand should have hesitated to gather the fruit within its grasp, since, in his eyes, it had scarcely ripened into full maturity? This, of course, is not the place to trace, step by step, the various inquiries which have gradually restored this hypothesis to its due position in chemical philosophy; but it deserves to be noticed that since the revolution in the ideas of chemists, caused by its recognition, the determination of vapour-densities, which for a time seemed to have lost some of its importance, has once more appeared in the foreground among the most prominent instruments of chemical inquiry.

There were other experimental researches of importance carried out by Dumas about this period. It had long been his intention to resume the study of the compound ethers, to which he had devoted considerable attention at Geneva. In the possession of a well-appointed laboratory, and supported by an able assistant, M. P. Boullay, he was justified in hoping that he might now succeed in consummating what he had formerly left incomplete. Dumas invited his assistant to join him in this inquiry, and this association seemed all the more promising since young Boullay had only to tread the footsteps of his father, who at an earlier date had been successfully engaged in similar researches.

The views regarding the nature of alcohol and ether accepted at that period agree with our present conceptions of these compounds more closely than the notions which for upwards of twenty years of the intervening time were held by the majority of chemists. On the faith of the analysis of Theodore de Saussure and the vapour density determination of Gay-Lussac, alcohol and ether were believed to consist of olefiant gas and water, viz:—

Alcohol of 1 vol. of olefiant gas and 1 vol of water,
Ether „ 2 „ „ „ 1 „ „

In the sense of this conception ether was looked upon as generated from alcohol by the abstraction of water from the latter, an opinion which had been first enunciated by Fourcroy and Vauquelin.

Dumas and Boullay commenced their experiments by supplying new analytical data in confirmation of the above-mentioned composition of alcohol and ether. They represent these substances by formulæ which, translated into our present notation, are as follows:—

Alcohol C_2H_4, H_2O
Ether $2C_2H_4$, H_2O.

Simultaneously they analyse the salts of sulphovinic acid first observed by Dabit, the formation of which they explain by the equation now accepted. They then proceed to an elaborate investigation of nitrous, acetic, benzoic, and oxalic ethers, the study of which had been commenced by Dumas at Geneva. The composition of these substances is finally settled by accurate combustions and vapour-density determinations. They further elicit by unequivocal experiments the capital fact that the decomposition of compound ethers by alkalies gives rise to quantities of acids and alcohol, the joint weight of which is greater than the weight of the compound ethers submitted to experiment, and by accurately determining this difference they succeed for the first time in establishing the nature of compound ethers on the solid foundation of experiment. It has been pointed out in a former part of this sketch that early in this century the compound ethers of oxacids were generally looked upon as generated by the union of alcohol with the so-called anhydrous acids; in 1825 Berzelius preferred to consider them as compounds of ether with hydrated acids, a view which simply involved the shifting of a molecule of water from the alcohol to the acid. On the other hand, it has been mentioned that Dumas, even by the early experiments performed at Geneva, had been led to doubt the correctness of the view prevalent at that time and to suggest that these substances must be looked upon as compounds of ether with anhydrous acids. And what he then hesitatingly suggested, Dumas, on the faith of his and Boullay's experiments, is now enabled positively to assert.

Moreover another order of ideas naturally presents itself to those who consider ether as formed by the union of water with olefiant gas. Compound ethers of the above constitution obviously appear to them as combinations of hydrated acids with olefiant gas, and Dumas and Boullay are thus legitimately led to argue that olefiant gas must be endowed with a very considerable combining power, which they aptly compare to that of ammonia. In a most striking synopsis, embracing a great variety of substances, they point out the perfect parallelism of the

compounds of olefiant gas with the salts of ammonia; thus chlorhydric ether consists of chlorhydric acid and olefiant gas, whilst sal ammonia is a compound of the former with ammonia. Again in oxalic ether and ammonic oxalate, oxalic acid is united in the former with olefiant gas, and in the latter with ammonia.

The investigations just mentioned lead to other inquiries teeming with most remarkable results. If the compound ethers are really ether compound, ether, Dumas argues, must be separable from them in one way or another. Their decomposition by the alkalies yields alcohol, because the water belonging to the alkalies participates in the reaction. In the presence of this difficulty the idea suggested itself to accomplish the desired effect by substituting dry ammonia gas for the alkalies. When performing the experiment Dumas arrives, almost simultaneously with Liebig, at the important result that the white substance generated in this reaction is identical with oxamide, the compound previously obtained by him when submitting ammonic oxalate to distillation; he finds, in addition, that the limited action of ammonia produces an intermediate body, oxamethane, which to-day we designate by the name of oxamate of ethyl. It is well known that a host of amides and amido-acids has since been generated by these reactions.

The discovery also of chloro-carbonic ether and urethane deserves to be briefly noticed here. Both the analysis of sugar and its transformation during fermentation permit us to regard this body as a compound of alcohol and carbonic acid. Directly, it is true, these substances refuse to combine, but there was a chance of carbonic acid, *in condicione nascendi*, being fixed by alcohol. In the sense of this conception Dumas submitted alcohol to the action of phosgen gas, hoping that a compound of the two substances would be formed. Such a compound, when treated with water, might have yielded chlorhydric and carbonic acids, and the latter might have remained united with the alcohol. It is true there is no sugar formed in this reaction, but the experiment led to the discovery of chlorocarbonic ether, which, in contact with ammonia, was converted into urethane or carbamate of ethyl. The composition of these two typical compounds, as established by Dumas, is that accepted nowadays, and what a harvest of fine discoveries has been reaped by other chemists on the field of investigation rendered accessible by these researches!

It is impossible to speak of the investigation of the compound ethers and the researches emanating therefrom, without alluding to the splendid papers on wood-spirit and spermaceti, jointly published by Dumas and Peligot, although they belong to a somewhat later period. The inflammable liquid generated by the destructive distillation of wood, and known as wood-spirit, had been discovered by Taylor as far back as 1812, but for twenty years the nature of this body had remained unknown. It had been examined by Liebig, it is true, but his experiments made with a compound, obviously containing foreign admixtures, had failed to solve the problem. It was then, in 1832, that Dumas and Peligot resumed this investigation. By renewed analysis of the perfectly purified body, by determining its vapour-density, and more especially by studying its behaviour with acids, they succeeded in establishing not only the true composition, but also the chemical character of this remarkable compound. They recognised wood-spirit to be a body exhibiting all the properties, slightly graduated, of alcohol—indeed, a second alcohol, differing from the alcohol *par excellence* by containing one atom of carbon and two of hydrogen less, an alcohol possessing its ether, producing with acids a series of compound ethers, which correspond to those derived from ordinary alcohol, and yielding, when treated with oxidising agents, an acid—formic acid—just as ordinary alcohol is converted into acetic acid. And scarcely had they completed this inquiry, the results of which were expressed with a clearness and precision excluding all doubt, when a second memoir on a similar subject was published by the indefatigable investigators. The saponification of spermaceti had yielded to Chevreul a solid compound, to which he had given the name of ethal, because its analysis had pointed out a certain analogy to ether and alcohol. Dumas and Peligot confirmed the analysis of Chevreul, but they at the same time proved by decisive experiments that this body is a third alcohol, differing from wood alcohol and wine alcohol by a multiple of the amount of carbon and hydrogen which distinguishes these two compounds from one another. And within less than a year another term was added to the list. An oily compound separated from potato spirit and analysed by Dumas, was recognised to be a fourth alcohol by Cahours, whose masterly researches proved it to hold a position intermediate between wine alcohol and the alcohol of spermaceti. No one, whose recollections do not stretch back to that already remote period, can possibly realise to-day the powerful impression which these discoveries, following each other in rapid succession, produced upon the minds of chemists. It may be compared, perhaps, to the sensation of the traveller, who, from the summit of a mountain looks down into the valley wrapt up in a dense mist. Vainly he endeavours to trace the features of the country, until at last the veil of clouds is rent, and through the rent a sunny bit of landscape appears. And again, the misty cover splits in a second and in a third place, and other spots of the vale gradually become visible, till imagination ventures to compound the landscape in all its beauty, though the clouds still impede the view in every direction. Such were the impressions of chemists when the four alcohols, one after another, arose like islands from the sea of the unknown. For many years these discoveries remained isolated; nevertheless investigators had gained as many landmarks by which they were henceforth enabled to steer their course.

It would be out of place, however, to pursue this subject any further, for every chemist knows that the classification of organic compounds by homologous series, which at a later period has been chiefly developed by Gerhardt, is founded on these early investigations of the alcohols.

Nor can we do more than allude to the influence which these researches, and more especially those respecting the compound ethers, have exerted on the progress of organic chemistry in several other directions. Some time after Dumas and Boullay had compared these substances to the salts of ammonia, chemists began to look at the latter from a novel point of view. As far back as 1816 Ampère had pointed out that by the assumption of a hypothetical metal, in one word, of ammonium, the idea of which had

first emerged on the occasion of Berzelius and Pontin's experiments on the electrolysis of ammonia salts, a perfect analogy might be established between the latter and the salts of the alkali metals. This conception, not much noticed at first, began to attract attention after Mitscherlich had proved the isomorphism of the salts of ammonia and those of potassium. But it was only in 1833, when some uncertainty still hanging over the composition of ammoniacal salts had been cleared away, that the ammonium theory, foreshadowed by Ampère's genius, and subsequently chiefly advocated by Berzelius, began to take root in the minds of chemists. Nor was it long before this change of view began to react upon the opinions held regarding the constitution of alcohol and ether. In the very same year, Kane suggested that in alcohol and ether a peculiar hypothetical compound, termed by him etherium, might be assumed, arising from the union of olefiant gas with hydrogen, exactly as ammonium is conceived to be formed by the association of that element with ammonia. It is obvious that a consistent development of this idea would have led up to the point of view from which we look at present on these compounds :—

$$\text{Alcohol, } C_2H_4, H_2O = C_2H_5HO.$$
$$\text{Ether, } 2C_2H_4, H_2O = 2C_2H_5, O.$$

But it is not always by the shortest road that science advances. Liebig adopted Kane's etherium, which now acquired the name of ethyl, as a constituent of alcohol and ether; but, perhaps chiefly in consequence of a change in the interpretation of the composition of water then gaining ground, he entirely abandoned the view entertained regarding the mutual relation of these two compounds. In his conception the molecules of ether and alcohol contain the same number of carbon atoms, the former being the oxide, the latter the hydrated oxide of ethyl. We cannot here undertake the task of dwelling on the powerful arguments which Liebig brought forward in favour of his opinion, nor glance at the immense services which the full elaboration of his ethyl theory has rendered to science, but we must not leave unnoticed the strange coincidence by which in the very moment when the isolation of ethyl by Frankland supplied the keystone, as it were, to this theory, the pre-ethylic views of Dumas and Boullay regarding the mutual relation of alcohol and ether were once more pressed into the foreground by Williamson's classical researches on the formation of ether, and Brodie's ingenious interpretation of ethyl free and ethyl combined. The unassailable logic of their arguments proved that though the conception of ethyl remain unscathed, the molecule of ether contains the double number of carbon atoms, which is present in that of alcohol, and thus it is that in a measure the ideas both of Dumas and Liebig have found expression in our present views regarding the constitution of these compounds.

But the impulse which the researches of Dumas and Boullay have given to the progress of organic chemistry is independent of the conflicting views held in succession respecting the nature of alcohol and ether. Their ether theory showed for the first time that the reactions accomplished within the organic domain of our science were capable of being represented by equations comparable in simplicity and precision to those which had formerly been believed to be the prerogative of mineral chemistry. It is from that point of view that this investigation will always be looked upon as forming an era in the history of organic chemistry. It was of comparatively little moment whether the compound ethers were analogous to the salts of ammonia or to those of potassium, as long as it remained established that these compounds were formed and decomposed by the same symmetrical reactions which had been so long observed in mineral chemistry. A first breach had been effected in the barrier which had hitherto separated the two chemistries, foreshadowing its imminent removal by Wöhler's grand experiment of the synthesis of urea.

While the experiments on the ethers sketched in the preceding paragraphs were still going on, a strange incident directed the attention of Dumas to a perfectly different order of phenomena, the study of which occupied him for many years of his life, and ultimately led him to one of his finest conceptions, the theory of substitution. It is not generally known that it is to a *soirée* at the Tuileries that the origin of the substitution-theory must be traced. One evening the visitors at the palace were greatly incommoded by irritating vapours diffused throughout the apartments, and obviously arising from the wax candles burning with a smoky flame. Alexandre Brongniart, in his capacity of director of the porcelain manufactory at Sèvres, was looked upon as chemist to the king's household, and it appeared but natural that he should be consulted respecting this unpleasant incident. Brongniart intrusted his son-in-law with the task of investigating the suspicious candles, and Dumas was all the more inclined to engage in this inquiry, that he had already made some experiments in that direction, having been asked by a merchant to suggest a method of bleaching certain kinds of wax which resisted the ordinary processes and thus remained unsaleable. Nor had Dumas any difficulty in supplying the explanation. The irritating vapours were chlorhydric acid, and it was thus obvious that the candle manufacturer supplying the palace had made use of wax bleached with chlorine, and that the chlorine-bleached wax had retained chlorine, which during the combustion of the wax was evolved in the form of chlorhydric acid. The origin of the inconvenience experienced at Charles X.'s *soirée* was thus satisfactorily explained and its recurrence easily obviated. At the same time it was proved by experiment that organic substances when treated with chlorine are capable of fixing this element in quantities far too large to admit the assumption of its presence being an accidental contamination. A new field of investigation was thus opened.

This account of the peculiar origin of the substitution-theory, which the author of this sketch owes to Dumas himself, is interesting in more than one respect. In any case it shows us that like the Luxembourg, the palace of the Tuileries, in addition to its historic traditions, has also its scientific associations. How strange! a sunbeam brilliantly reflected from the windows of the Luxembourg and casually observed by Malus through a plate of Iceland spar, unveils the phenomena of polarisation, adding a new province to the domain of physics, while the irritating vapour emanating from the wax lights dimly burning in the ball-rooms of the Tuileries induces Dumas to examine

the action of chlorine upon organic substances, and thus gives rise to speculations as to the nature of chemical compounds, which for years have exerted and are still exerting a powerful influence upon the progress of chemistry.

The mineral section of our science had already made considerable advances, when, at the beginning of the second quarter of this century investigators began to devote their whole energies to the study of organic chemistry. No wonder that the results of these studies should have appeared to them in the same light in which they had hitherto been in the habit of regarding the phenomena of inorganic nature. Thus it happened that the views then generally accepted of the construction of mineral compounds were also naturally applied to that of organic bodies. It was more especially in the sense of the electro-chemical theory, chiefly advocated by Berzelius and founded by him on the behaviour of mineral salts within the galvanic circuit, that the interpretation of organic substances was attempted. All compound bodies were looked upon as formed by the juxtaposition of two proximate constituents, perhaps compounds themselves, and, if so, generated again by the union of two components; and this mode of sub-division was conceived to be continued until ultimately binary constituents were reached, the components of which were elementary atoms. According to this view, each element was endowed with a special—the so-called electro-chemical—character, determining its chemical behaviour and also influencing that of its compounds. It was, moreover, upon this electro-chemical character that the particular constituent depended of which, in a complex body, the element in question could form part. Various metals, owing to the similarity of their electro-chemical character, were believed to be capable of forming oxides of similar basic properties. The electro-chemical character of hydrogen was regarded as being still so far analogous to that of the metals as to confer upon its oxygen compound, water, basic properties similar to those of the metallic oxides, and enabling it to enter, like the latter, into combination with acids. The electro-chemical character of chlorine, on the other hand, was held to approximate closely to that of oxygen and to differ absolutely from that of the metals and also of hydrogen; so that the formation of analogously constituted compounds by the union of hydrogen with certain elements and of chlorine with the same elements appeared to be absolutely out of the question. Diametrically opposed to these conceptions were the views at which, soon after 1830, Dumas had arrived by his researches, and which for the first time he made known in a more connected form, when publishing, in 1834, his experiments upon chloral, to which we shall have to refer hereafter.

The fact of chlorhydric acid being formed when organic substances are acted upon by chlorine and of this element being at the same time fixed by such substances had been observed by several inquirers, and more especially by Gay-Lussac, who had perceived it in the case of prussic acid, and, as we are informed by Dumas himself, had seen it even in wax, the very substance which was the starting-point for his experiments. Nor had it escaped Faraday or Liebig and Wöhler, who had witnessed it, the former when studying Dutch liquid, the latter when engaged in their celebrated investigation of oil of bitter almonds. Some of these inquirers had actually pointed out that the amount of chlorine fixed was equivalent to the quantity of hydrogen eliminated. But these observations had remained isolated; no one had thought of regarding them from a general point of view, and we can imagine the strange surprise, bordering on disdainful incredulity, with which chemists listened to Dumas when he summoned them to uproot their binary conceptions and to acknowledge the new doctrine of chlorine being capable of replacing hydrogen, atom for atom, in organic compounds. It is true that the phenomenon of substitution, for which the author of the new theory happily proposed the designation metalepsis (μετάληψις, exchange), is not invariably observed in all its purity; but discrepancies are sufficiently explained by secondary circumstances. If a compound loses more hydrogen than it fixes chlorine, it may be that this excess of hydrogen is present and may therefore be eliminated in the form of water, or if the gain of chlorine be greater than the loss of hydrogen it may be that the chlorhydric acid generated remains in combination with the substitution product newly formed. And the effects produced by chlorine, of course, are also observed when organic substances are acted upon by bromine and iodine, and even by nitric and sulphuric acids, fragments of which are found to replace hydrogen like the elementary halogens.

It cannot cause surprise that views so totally at variance with the notions of the times should have at first encountered violent opposition. Still chemists were soon stirred with the presentiment of something like the dawn of a new morning in their science. A new idea had taken hold of their minds—the idea that it is not so much the quality of the elementary atoms united in a body and their progressive binary association that impress its chemical physiognomy upon a compound, as the number of those atoms and the structural order in which they are disposed to form a unitary edifice. Nevertheless, as we glance retrospectively at the development of science, we are obviously in a much more favourable position than were Dumas's contemporaries fifty years ago, for appreciating the fertile germ contained in his ideas, and we are certainly better able than were the chemists who had to disentangle themselves from cherished notions, to admire the daring grasp and thoughtful reflection with which, upon a comparatively narrow foundation of data furnished by experience, Dumas ventured to raise the noble structure of his far-reaching conceptions. But in the early deduction of important inferences which are fully confirmed by subsequent discovery, we recognise here, as often in science, the genius of him who knew how to draw them.

Though vehemently opposed by Berzelius and his school, who exhausted the resources of argument, scorn, and even ridicule against them, Dumas's ideas rapidly took root, and but a few years later substitutional conceptions began to prevail in the researches of the younger generation of chemists. An additional impetus was given to the movement, when it was joined by Laurent who, though often so much at variance with Dumas, as to become, more especially in consequence of questions of priority as to certain collateral ideas, his declared opponent, has nevertheless, by amplifying the original conceptions and by presenting in his unremitting

researches ever new and welcome illustrations of them, assisted more perhaps than any other chemist, in the propagation of the theory of substitution.

It would be a grateful though arduous task to trace in its various stages the influence which this theory has exercised upon the development of chemical ideas. Such a task, however, lies beyond the limits of this notice, and we must be satisfied to sketch in a few brief outlines what might be made the subject of a comprehensive essay. It is more especially organic chemistry, the mother of this theory, which has reaped the largest harvest of results from it, but mineral chemistry too has been greatly benefited by its growth. Indeed it was under the influence of substitutional ideas that Laurent, entirely breaking with binary traditions, first exhibited the relation of potash to water in the light of the new theory, and thus, by regarding potash as water in which an atom of hydrogen is replaced by an atom of potassium, opened a line of thought the fertility of which is not yet exhausted. In organic chemistry substitutional ideas have for many years remained prevailing. The great researches on etherification by Williamson, those on the derivatives of ammonia by Wurtz and others, and those on the anhydrous acids by Gerhardt, which marked the middle of the century, were essentially substitutional in their conception, execution, and exposition. And when somewhat later Gerhardt, endeavouring to set forth the whole range of chemical discovery in the light of these researches, established his well-known three types, his classification appeared but as an expansion of the theory of substitution. And though the narrow framework of these types could not long hold the daily increasing mass of newly discovered compounds, and the introduction of the mixed types—chiefly due to Kekulé and Odling—as well as the important addition of the marsh-gas type to those of chlorhydric acid, water, and ammonia, broke the limits of the old view, yet these new acquisitions were but further stages of the same thought, and the progress of chemistry was still moving on the lines of the theory of substitution.

It is still in the recollection of every one that even these augmented types soon proved insufficient for the growth of science, whose rich and unexpected results they could receive only with difficulty, by constraint and with ever-increasing uncertainty, and that chemists, guided by Kekulé's genius, who taught them to study the specific attractions of elementary atoms, have learnt to trace the architecture of chemical compounds without the assistance of substitutional and typical considerations. Still, whenever we study the past and the future of a compound, when we examine long series of bodies connected with each other, the simplest mode of looking at these transitions is still to consider them as processes of substitution. And if in the light of our present views the formation of compounds by the substitution of chlorine for hydrogen appears to us almost self-evident, let us not forget that it was a noble daring to advance this idea in 1830; and if to-day we delight in the transparency of our structural formulæ, let us ever gratefully remember that we cannot but regard them as the realisation of conceptions of which Dumas was possessed half a century ago, when, in opposition to the views of the time, he insisted upon the fact of chemical substances owing their properties much less to the quality of their elementary atoms than to the order of collocation of these atoms within the compound, which our structural formulæ endeavour to depict.

Speaking of the influence of the theory of substitution on the progress of chemistry, we are tempted to insert here, by way of parenthesis, a *bon mot* of Liebig's on the subject. The International Exhibition of 1867 had assembled in the French metropolis a great number of chemists of all nations, who were most hospitably received by their colleagues. It was on this occasion that Dumas and Liebig were again brought together after an interval of many years. At that time the author of this sketch had the good fortune of associating with them frequently at the meetings of the Council of Chairmen of the Exhibition, and nothing could surpass the cordiality of their intercourse. Nor was it long before an opportunity was afforded them of giving public expression to the friendly feelings by which they were animated. The chemical visitors to the Exhibition of 1867 are sure to remember the magnificent banquet at the Trois Frères Provençaux to which they were invited by their French colleagues. Dumas was in the chair, while Liebig sat opposite him, and it was a delight not easily forgotten to listen to the professions of mutual regard and good fellowship exchanged by the two antagonist champions of yore, who in early life had had so many fierce encounters. In the course of conversation Dumas asked his quondam opponent how it was that for years he had exclusively devoted himself to agricultural chemistry. "I have withdrawn from organic chemistry," replied Liebig; "for with the theory of substitution as a foundation, the edifice of chemical science may be built up by workmen: masters are no longer needed." Of course no one would take an after-dinner speech *au sérieux*. But Liebig's reply shows, nevertheless, how thoroughly he must have been converted to the importance of the substitutionary interpretation of chemical phenomena.

We cannot, of course, attempt to examine in detail the several experimental researches extending over a considerable space of time and embracing a great variety of subjects, which served as scaffolding to Dumas when building up his substitutional and typical conceptions, nor can we trace in its many sinuosities and ramifications the fluctuating stream of ideas, expanding and contracting according to the nature of obstacles opposing its progress; all we can do is to allude in a few words to the experiments which furnished him with his principal illustrations.

Proceeding chronologically, we should have to refer in the first place to Dumas's experiments on cinnamon oil and cinnamic acid. The action of chlorine upon cinnamon oil gives rise to a well-defined substitution product—

Cinnamon Oil	$C_9H_8\ O$
Chlorocinnose	$C_9H_4Cl_4O$,

and what interests us perhaps still more is that cinnamon oil and cinnamic acid, *mutatis mutandis*, appear in these researches with the formulæ nowadays acknowledged from which their mutual relations is unequivocally reflected—

Cinnamon Oil	C_9H_8O	Aldehyde.
Cinnamic Acid	$C_9H_8O_2$	Acid.

Again, some excellent illustrations of substitution are furnished by olefiant gas and ordinary ether—

Olefiant Gas	C_2H_4
Dichlorinetted Olefiant Gas ...	$C_2H_2\ Cl_2$
Ether	$C_4H_{10}\quad O$
Tetrachlorinetted Ether	$C_4H_6\ Cl_4O$.

Among the substances the study of which promised to elucidate the laws of substitution, ethylic alcohol more especially claimed the attention of inquirers. Dumas did not hesitate to take up this subject, but he was forestalled by Liebig, who, although by no means a sharer of Dumas's opinions at that time, had been led, perhaps even with the view of disproving them, to the same investigation. By studying the action of chlorine upon alcohol, Liebig, as is well known, discovered chloroform and chloral; and these two substances, which, since Sir James Simpson and Oscar Liebreich pointed out their physiological properties, are in constant use for the alleviation of human suffering, may in a certain sense be looked upon as children of the theory of substitution. But if Dumas lost the discovery of chloroform and chloral he has had at all events the satisfaction of establishing the true composition of these two compounds and of thus supplying the key to the correct interpretation both of the formation of chloral from alcohol and of its decomposition, first pointed out by Liebig, into formic acid and chloroform, when submitted to the action of alkalies. The equations

$$C_2H_6O \quad + Cl_8 \ = C_2HCl_3O + 5HCl$$

and

$$C_2HCl_3O + H_2O = CH_2O_2 \quad + CHCl_3$$

are Dumas's. It was chiefly by determining their vapour densities that he succeeded in making out the true nature of these compounds. The new formulæ which he substituted for those originally proposed by Liebig elucidated the whole inquiry, so as to exclude all doubt. Liebig used to say that it was worth while being corrected, as he had been by Dumas, as to the interpretation of the action of chlorine on alcohol. Indeed at a later period he quoted this case in order to show how experimental controversy should be conducted :—"As an excellent illustration of the mode in which errors should be corrected," Liebig said, "the investigation of chloral by Dumas may fitly be adduced. It carried conviction to myself and, I think, to everybody else, not by the copious number of analytical data opposed to the not less numerous results which I had published, but because these data gave a simpler explanation, both of the formation and of the changes of the substances in question. To analytical data alone no one—and Dumas least of all—would have attached the slightest importance."

The investigations adverted to having proved chloral to be a substitution-product of aldehyde—a trichlorineted aldehyde—we are naturally led to glance at an inquiry which, more perhaps than any other, has contributed to establish Dumas's ideas in the minds of chemists. We allude to his splendid researches on the action of chlorine upon acetic acid. The beautiful white crystalline compound which is formed when glacial acetic acid is treated with chlorine under the influence of sunlight is trichloracetic acid holding to acetic acid exactly the same relation which obtains between aldehyde and chloral.

Aldehyde ...	$C_2H_4\quad O$	Acetic Acid	$C_2H_4\quad O_2$
Chloral ...	$C_2H\ Cl_3O$	Trichloracetic Acid	$C_2H\ Cl_3O_2$.

It retains all the characteristic properties of the mother compound, its salts and its ethers resemble those of acetic acid, and when Berzelius and the champions of dualistic views still endeavoured, by constrained interpretation, to prove acetic and chloracetic acid to differ in constitution, Dumas showed that even their metamorphoses are strictly analogous. When submitted to the action of alkalies both acids yield carbonic acid, accompanied in the former case by marsh-gas and in the latter by chloroform—

$$C_2H_4 \quad O_2 = CO_2 + CH_4$$
$$C_2H\ Cl_3O_2 = CO_2 + CH\ Cl_3.$$

The formation of marsh-gas and chloroform in these two analogous reactions can leave no doubt as to the mutual relation between these two substances, the latter being a substitution-product of the former. Nor did Dumas find any difficulty in proving this relation by direct experiment, for on submitting marsh-gas to the action of chlorine he succeeded in converting it into chloroform and even into tetrachloride of carbon—

Marsh-gas	CH_4
Chloroform	$CH\ Cl_3$
Tetrachloride of Carbon	$C\quad Cl_4$.

Experiments nearly simultaneously performed by Dumas in conjunction with Kane on the behaviour of acetone with chlorine, yielded similar results; they did not, it is true, obtain the last product suggested by theory, but only one of the intermediate substitution-products—

Acetone	$C_3H_6\quad O$
Tetrachloracetone	$C_3H_2Cl_4O$.

In his paper on chloracetic acid Dumas quotes, moreover, the transformation of oil of bitter almonds into chloride of benzoyl—

Oil of Bitter Almonds	$C_7H_6\quad O$
Chloride of Benzoyl	C_7H_5ClO

as a good illustration of phenomena of substitution. At the same time he directs the attention of chemists to the close analogy between acetic and benzoic compounds, embodying in the synoptical table drawn up for this purpose several then hypothetical substances which the progress of chemistry has not failed to call into existence.

Among the numerous researches undertaken with the view of elucidating the theory of substitution, a joint inquiry by Dumas and Stas on the action of alkalies on alcohols and ethers must not be forgotten. A glance at the formulæ of alcohol and acetic acid shows that the former may be looked upon as a substitution-product of the latter, two atoms of hydrogen replacing one of oxygen—

Acetic Acid	$C_2H_4O_2 = C_2H_4O\ O$
Alcohol	$C_2H_6O \ = C_2H_4H_2O$.

Supposing the change of the two compounds under the influence of alkalies to be strictly analogous, carbonic acid, which in the case of acetic acid, is accompanied by marsh-gas, should in the case of alcohol, be replaced by methylic aldehyde—

Acetic Acid...	$C_2H_4O\ O = CH_4 + C\ O\ O$
Alcohol... ...	$C_2H_4H_2O = CH_4 + CH_2O$.

Experiment yielded a different result. Instead of marsh-gas pure hydrogen is evolved; a molecule of water participates in the reaction converting the aldehyde into carbonic acid, which remains in combination with marsh-gas—

$$C_2H_6O + H_2O = C_2H_4O_2 + H_4.$$

The acetic acid thus generated, when more strongly heated is, of course, decomposed into marsh-gas and carbonic

acid. A perfectly analogous behaviour is exhibited by other alcohols. Amylic alcohol, then just brought to light by Dumas's and by Cahours's researches, is found to yield valeric acid, up to that time obtained only from *valeriana officinalis*—

$$C_5H_{12}O + H_2O = C_5H_{10}O_2 + H_4,$$

whilst ethal or cetylic alcohol, isolated, as we have pointed out in an earlier part of this sketch, by Dumas and Peligot from spermaceti, furnishes the acid belonging to it, now called palmitic acid—

$$C_{16}H_{34}O + H_2O = C_{16}H_{32}O_2 + H_4.$$

The only exception to the rule is methylic alcohol, which yields oxalic instead of formic acid; but it is known from Peligot's experiments that formic acid when fused with potash is converted into oxalic acid and hydrogen—

$$\begin{aligned} CH_4O + H_2O &= C\,H_2O_2 + H_4 \\ 2CH_2O_2 &= C_2H_2O_4 + H_2. \end{aligned}$$

In the same paper Dumas and Stas examine the behaviour of many other compounds closely allied to the alcohols under the influence of potash, such as glycerin, aldehyde, acetone, and compound ethers, the changes of which are minutely described. It is of particular interest to perceive the clear foreboding with which at a period when but a few alcohols were known, the authors of this remarkable paper anticipated the importance of this class of compounds. "The recognition of an alcohol," they say, "enriches organic chemistry with a series of compounds comparable to those with which mineral chemistry is endowed by the discovery of a new metal. As yet we know only how to transform an alcohol into the corresponding acid; of equal if not greater importance would be the inverse process, the conversion of acids into alcohols. There can be no doubt that this problem also will ere long be solved." The chemical reader need not be reminded that the prediction has long since been verified to the letter.

And here we must not omit to add, by way of parenthesis, that a few years later Dumas returned once more to the acids generated by the oxidation of the alcohols. But on this occasion it is not their mode of derivation from the alcohols which fixes his attention. The simple relation in which these acids stand to each other has not escaped his observation. For the first time, indeed, we hear of the series of fatty or aliphatic acids. In a previous part of this sketch we have pointed out that the researches on methylic, amylic, and cetylic alcohols must be looked upon as the starting-point for the classification of organic compounds in homologous series. A very important series of this kind was indicated by Dumas when in 1843 he showed that between formic and margaric acids not less than fifteen acids could be assumed to exist, differing from one another by a constant elementary difference, CH_2, of which nine at least were known at that time—

Formic Acid	... $C\,H_2\,O_2$	— —	... $C_{10}H_{20}O_2$
Acetic "	... $C_2H_4\,O_2$	— —	... $C_{11}H_{22}O_2$
— —	... $C_3H_6\,O_2$	Lauric Acid	... $C_{12}H_{24}O_2$
Butyric "	... $C_4H_8\,O_2$	— —	... $C_{13}H_{26}O_2$
Valeric "	... $C_5H_{10}O_2$	Myristic "	... $C_{14}H_{28}O_2$
Caproic "	... $C_6H_{12}O_2$	— —	... $C_{15}H_{30}O_2$
Œnanthic "	... $C_7H_{14}O_2$	Palmitic "	... $C_{16}H_{32}O_2$
— —	... $C_8H_{16}O_2$	Margaric "	... $C_{17}H_{34}O_2$
Capric (?) "	... $C_9H_{18}O_2$		

The fusing points of these acids rise with the number of carbon atoms in their molecules. It need not be mentioned that the terms of the series not known at the time have long since been discovered.

Nor must we, in glancing at the several inquiries illustrating the theory of substitution in conclusion omit to refer in a few words to Dumas's researches on indigo, although their chief outcome is not immediately connected with this question. Dumas in the first place finally established the composition of indigo, which had already been correctly analysed by Walter Crum, and then fixed the relation which obtains between blue and white indigo. With the view of ascertaining the molecular weights of the two indigos he studied the sulpho-acids, which are generated by the action of sulphuric acid upon blue indigo. For the formulæ of blue and white indigo as well as of the sulpho-acids—

Blue Indigo	$C_{16}H_{10}N_2O_2$
White Indigo	$C_{16}H_{12}N_2O_2$
Sulphopurpuric Acid ...	$C_{16}H_{10}N_2O_2SO_3$
Sulphindigotic Acid ...	$C_{16}H_{10}N_2O_2(SO_3)_2$,

we are indebted to Dumas, as also for those of anilic and carbazotic acids, now called respectively nitrosalicylic and picric acid—

Anilic Acid, $C_7H_5N\,O_5 = C_7H_5(NO_2)O_3$ { Nitrosalicylic Acid.

Carbazotic Acid, $C_6H_3N_3O_7 = C_6H_3(NO_2)_3O$ { Trinitrophenol.

And it deserves particularly to be mentioned that when Laurent had established the composition of Runge's carbolic acid, termed by him phenol, Dumas was the first to point out that carbazotic or picric acid may be looked upon as the trinitro-derivative of carbolic acid or phenol—

Phenol	$C_6H_6\quad O$
Picric Acid	$C_6H_3(NO_2)_3O$.

The number of elements with which organic chemistry works in building up her structures being so very limited, it was but natural that from the very first considerable attention should have been bestowed upon the quantitative analysis of organic substances. Indeed, we find the very chemists who laid the foundation of organic chemistry also engaged in elaborating the methods for determining the organic elements. It would have been strange if Liebig and Dumas had not shared in the early presentiment of the importance of organic analysis, since so nobly confirmed by the marvellous growth of our science. There are, indeed, no two chemists to whom we are more deeply indebted for the growth of our methods of analysing organic substances than Liebig and Dumas, and we are delighted that in the language of the laboratory, their names remain associated with the processes they have introduced. We speak of Liebig's method of estimating carbon and hydrogen, and of Dumas's process for determining nitrogen. The latter, the so-called volumetric process, consisting as it does in collecting the products of combustion, carbonic acid, and nitrogen in a graduated cylinder over potash, and thus measuring the nitrogen, is so constantly made use of that we need scarcely dwell on its importance. It is so simple in principle, and so easy of execution, that those who are in the daily habit of working with it, almost forget that it was ever invented. And yet how complicated and

constantly varying were the plans which both Dumas and Liebig employed in their early researches! How long were they compelled to rely upon what was called the qualitative method, which consisted in ascertaining the ratio of the volumes of nitrogen and carbonic acid disengaged during combustion! It is interesting to follow step by step the efforts made by Dumas to improve this method. Indeed, since the process becomes less accurate as the percentage of nitrogen diminishes, we find that in order to augment this percentage he does not shrink from converting the substances when they are acids or bases, into ammonia salts or nitrates, and submitting them thus enriched in nitrogen to combustion. It is true Dumas's is no longer, as it was for a long time, the method exclusively adopted; a powerful rival has arisen to it in Will and Varrentrapp's ammonia-process, but it is only justice to Dumas to remember that many years previously he had himself adapted the principle involved in this process to analytical determinations, having actually estimated the nitrogen in substances not convertible into ammonia salts or nitrates, by fusing them with potash and collecting the ammonia disengaged over mercury; nor should it be forgotten that whilst the ammonia process is excluded in many cases, the volumetric method is of universal application.

Speaking of the methods of determining the composition of organic substances, it is but natural that we should allude in this place to the services which Dumas has rendered to organic analysis, by the revision jointly carried out with Stas of the atomic weight of carbon. The origin of this revision was the observation made by him and others, that the joint amount of carbon and hydrogen obtained by the combustion of hydrocarbons rich in carbon, almost always apppreciably exceeded the weight of the substance burnt. How was this excess to be explained? Was there a constant error in the method of analysis, or could it arise from the composition of water having been inaccurately determined? Experiments made by the authors seemed to answer both these questions in the negative, so that the only solution of the difficulty that presented itself lay in assuming the determination of the atomic weight of carbon to be inaccurate. The authors now proceed to determine, with every precaution imaginable, the ratio in which carbon unites by weight with oxygen, in order to find the true weight of the carbon atom. For this purpose graphite, native and artificial, as well as diamonds, are burnt in a current of dry oxygen. They arrive in this manner at the number 12 instead of 12·24, which was the number adopted by Berzelius. Numerous very careful analyses of substances, the atomic constitution of which could not be doubted, such as benzol, naphtalin, benzoic and cinnamic acids, camphor, &c., while showing the inadmissibility of the old number, corroborate the new value. The reason why, notwithstanding the use of the high carbon atom, the errors of carbon determinations did not invariably prove positive, may be explained by combustion in organic analysis being never absolutely perfect, and also by minute quantities of water evaporating from the potash in the bulb-apparatus by the current of gas. Dumas and Stas's investigation will ever be looked upon as a model for experimental researches; and their atomic weight of carbon has since been universally adopted.

The views arrived at in this inquiry also led naturally to a revision of the atomic weight of oxygen, in other words to a revision of the composition of water, which appeared all the more desirable, since chemists at that period very generally began to use the atomic weight of hydrogen as the atomic unit instead of that of oxygen which had been previously employed. Volumetrically the composition of water was accurately known at that time. It will be remembered that the first experiments of Lavoisier and Meunier had led them to consider water as formed by the union of 100 volumes of oxygen with 192 volumes of hydrogen; again, the later experiments made on a much larger scale by Fourcroy, Vauquelin, and Séguin had furnished them the ratio of 105 to 200, but the simple ratio of 1 : 2 did not present itself to the minds of these chemists; its recognition at a somewhat later period was reserved for Gay-Lussac and Humboldt. The volumetric composition being established beyond a doubt, it was easy to calculate the ponderal composition, supposing the volume weights of the two gaseous constituents to be accurately fixed; and, on the other hand, the volume weights of these gases admitted of determination, the ponderal composition of water having been accurately made out. At the time of which we speak (in 1842), 100 parts by weight of oxygen were, on the authority of Berzelius, believed to be united with 12·479 parts of hydrogen, and the volume weight of oxygen to be 15·973, hydrogen being 1. Was it legitimate to admit the simplification of this ratio suggested by these numbers? A reply to this question could be furnished by experiment only. Experiments made by Dumas on a scale not hitherto attempted, and consisting in the reduction of large quantities of oxide of copper—from 300 to 900 grms. were used—and determining the oxygen supplied by the oxide as well as the water formed, showed the volume weight of oxygen to be exactly 16, and thus the fundamental numbers 1, 12, and 16 for hydrogen, carbon and oxygen became once for all an inalienable acquisition of chemical philosophy.

Dumas was induced, it is true, nearly thirty years afterwards, to return once more to the subject by some startling statements advanced by Dubrunfaut, who believed himself to have proved that carbon could be burnt by oxygen in the presence of water only, and consequently that oxygen, hitherto considered to be dry, still contained appreciable quantities of water. Repeating the combustion of carbon in oxygen with every precaution, Dumas found, indeed, that it is well nigh impossible to remove the last traces of moisture from oxygen, but that its amount is far less than appeared to result from Dubrunfaut's experiments, and that it does not affect in any way the value which his early researches had established for the atomic weight of carbon.

The corrections to which the experiments previously mentioned had led, as regards the composition of carbonic acid and water, suggested also a re-examination of atmospheric air. Dumas undertook this investigation in conjunction with his friend Boussingault. The method of analysis adopted was exclusively ponderal. Dry atmospheric air was slowly drawn through a tube containing ignited copper into a large glass globe exhausted by the air-pump. The increase in weight of the copper furnished the oxygen by weight, while the nitrogen in the globe was weighed directly. They found in this manner that 100

parts by weight of air contain 23 parts by weight of oxygen and 77 parts by weight of nitrogen. But on calculating with the volume weights of oxygen and nitrogen then accepted, the composition of air by volume, they arrived at an appreciable deficiency. If a and b represent respectively the volume weights of oxygen and nitrogen referred to air, there is obviously

$$\frac{23}{a} + \frac{77}{b} = 100,$$

and by substituting for a and b the values then generally adopted, they found

$$\frac{23}{1\cdot1026} + \frac{77}{0\cdot976} = 99\cdot76,$$

and were thus led to suspect these volume weights to be incorrect. Indeed, new experiments carried out with most scrupulous care furnished the slightly modified values 1·1057 and 0·972, which very nearly satisfied the conditions of the equation,

$$\frac{23}{1\cdot1057} + \frac{77}{0\cdot972} = 100\cdot02.$$

The composition of air thus arrived at by Dumas and Boussingault is—

	By Weight.	By Volume.
Oxygen	23	20·81
Nitrogen	77	79·19
	100	100·00

These results were obtained at Paris. It is well known that experiments simultaneously made by Stas at Brussels, by Marignac at Geneva, by Brunner at Berne, by Lewy at Copenhagen, and by Derver at Groningen, all working by the same method, have led to values very nearly coincident.

The rectification of the atomic weight of carbon, and the inquiries more immediately connected therewith, must be looked upon as the prelude to Dumas's long series of researches on the atomic weights of the elements. They were mostly published at a later period (from 1858 to 1860), and obviously occupy the author even at the present moment, the most recent paper—one of very considerable interest—having been but lately (1878) published.

Berzelius, who devoted so many years of his life to the accurate determination of these weights, could not persuade himself that the numerical relations of these values indicated a more intimate connection of the elements with one another, a common origin, as it were, of the elements. He thought these apparent relations would more and more disappear the better the atomic values were determined. For him there existed as many forms of matter as there are elements; in his eyes the molecules of the different elements had nothing in common except their inalterability and their eternal existence.

On the other hand it was pointed out by Prout that the atomic weight of hydrogen being taken as unit, a great many of the weights of other elementary atoms are multiples by integral numbers of that of hydrogen, a fact which appears to foreshadow the existence of what might be called a primordial matter, presenting itself in different stages of condensation, to each of which one of our actual elements would correspond. Indeed, after physicists had established the unity of forces, by showing that heat, electricity, magnetism, &c., are but manifestations of the same agent, differing from, but convertible into, one another, was it not to be expected that chemists should succeed in experimentally demonstrating the convertibility into one another of the several kinds of substances regarded as simple bodies and thus prove the unity of matter? The elements of mineral chemistry would thus become comparable to the radicles of organic chemistry containing the same elements, from which they would differ only by their greater stability and by their being *pro tempore* undecomposable.

We need not dwell upon the fascination which this idea has for speculative minds, nor are we surprised that Dumas should feel attracted to the examination of Prout's hypothesis, so deeply affecting the very foundation of chemical philosophy.

Are the atomic weights of all elements really multiples of that of hydrogen? This, of course, is the first question. But there are others closely connected with it. On comparing the atomic weights of three elements forming a natural group, is that of the intermediate term exactly the arithmetic mean of those of the extremes? Again, are there constant differences observed between the atomic weights of elements such as are presented when the molecular weights of the several terms of a series of organic homologues are compared? These are some of the questions examined by Dumas in succession. His investigations have unveiled or elucidated a number of relations hitherto unobserved or but imperfectly indicated, all of which are sure to receive, some day, their unequivocal interpretation, when once the key to this order of phenomena shall have been found. As yet, however, the results arrived at have not attained the compact simplicity which would admit of compressing an account of these several inquiries within the narrow compass of this notice. A few fragmentary statements must suffice to convey to the reader an idea of the magnitude and variety of these researches. They embrace not less than thirty elements, or about one-half of those then known; the number of experiments made for the purpose of fixing their atomic weight closely approach two hundred, so that on an average about six separate analyses were made in each case. These determinations prove that Prout's hypothesis is by no means verified in all cases; still the atomic weights of not less than twenty-two elements are multiples by integral numbers of that of hydrogen, whilst seven, are multiples of half, and three of one-fourth that value. As regards the notion of the atomic weights of intermediate elements being expressed by the arithmetic mean of those of their analogues, it also cannot be looked upon as strictly correct. It is true for lithium (7), sodium (23), and potassium (39), but clearly cannot be maintained for chlorine (35·5), bromine (80), and iodine (127), the arithmetic mean, $\frac{35\cdot5 + 127}{2} = 81\cdot25$, differing very appreciably from the atomic weight experimentally determined. Lastly these researches unmistakably point to the existence of differences in the atomic weights of elements resembling those which are exhibited by the molecular weights of homologous compounds in organic chemistry. As an illustration of relations of this kind, the following elements may be quoted:—

Lithium	7
Sodium	$7+1\times16=23$
Potassium	$7+2\times16=39$

Oxygen	16
Sulphur	$16+1\times16=32$
Selenium	$16+4\times16=80$ (78)
Tellurium	$16+7\times16=128$
Magnesium	24
Calcium	$24+1\times16=40$
Strontium	$24+4\times16=88$ (87·2)
Barium	$24+7\times16=136$ (137·2)

It is well known that many of Dumas's atomic weights have since been slightly modified by Stas's classical researches upon the same subject, in consequence of which Prout's hypothesis has lost many of its partisans. The question, however, is still an open one, and it deserves especially to be noticed that Dumas has lately, by a series of indisputable experiments, proved the very important and quite unexpected fact that silver occludes, in the solid state, very appreciable quantities of oxygen, which are set free when the metal is strongly heated for some time *in vacuo*. Silver having been the starting-point for the determination of so many atomic weights, it is obvious that all these experiments have to be repeated before the question can be looked upon as finally settled.

Dumas's principal researches in organic chemistry have been mentioned in connection with his theory of substitution. There are, however, some inquiries, to which we have still to refer, among them in the first place to his experiments on the nitriles. It had been long known that the harmless formate of ammonium, when it loses the elements of water, is converted into the most virulent of poisons, prussic acid, and as early as 1832 Pelouze had pointed out that the latter, by fixing water, is capable of being reconverted into the ammonium salts of formic acid. These experiments led him to investigate also the ethers of hydrocyanic acid, and more especially cyanide of ethyl, the discovery of which had nearly cost him his life. It did not, however, occur to him to examine also the action of water upon this ether, in order to generate an ammonium salt analogous to formate of ammonium. To some it may appear strange, perhaps, that an experiment which naturally suggests itself to us, should have been omitted. But we must not forget that these researches belong to a period already far remote, when chemists had but a faint presentiment of the homologous series so familiar to us. Indeed, it will convey an idea of the immense strides organic chemistry had still to make, if we learn that many years had yet to elapse before the generality of this reaction, of which we have since made such extensive use in the most varied departments of the science, was recognised. In 1844 Fehling discovered benzonitrile, but it was only in 1847 that the full importance of the reaction was pointed out in different quarters. In the first place Kolbe and Frankland showed that cyanide of ethyl, when fixing the elements of water yields the higher homologue of formic acid, then called metacetic acid, whilst shortly afterwards it was proved by Dumas that ammonium acetate, when submitted to powerful agents of dehydration, such as phosphoric anhydride, is converted into cyanide of methyl, identical in every respect to that obtained by the action of methyl sulphates on cyanide of potassium. In conjunction with Malaguti and Leblanc, Dumas subsequently continued these researches, showing that the amide is even better suited for the preparation of the nitrile than the ammonium salt, and repeating the experiment, more especially with the derivatives of propionic and valeric acids. It is, indeed, on this occasion that the term "propionic acid" first appears in literature. The name was given by Dumas to the substance formerly called "metacetic acid." This substance separates as an oily layer upon its saturated aqueous solutions—a property belonging neither to formic nor acetic acid—and may thus be regarded as the first of fatty acids (πρὸ and πίων). It is well known that from the term propionic acid the three-carbon series have received their name.

In sketching the earlier part of Dumas's scientific labours, we have had to advert to the important physiological researches which, together with Prévost, he prosecuted at Geneva. We saw how, after his removal from that city, and owing to the peculiar associations by which he was surrounded at Paris, his attention became more and more directed to chemical and physical inquiries. It would have been strange, however, if the favourite studies of younger days had not, in a measure, retained hold of him during later life. And, indeed, we repeatedly find him engaged once more in chemico-physiological investigations, more especially when, after the death of Deyeux, he had accepted the chemical professorship in the École de Médecine. In consequence of general conceptions regarding the links of connection between vegetal and animal life, simultaneously advanced by Liebig in Germany and by Dumas and Boussingault in France, to which we shall have to allude again hereafter, great exertions were then made by chemists to prove the identity of composition of the neutral nitrogenous compounds existing both in the vegetal and animal organism, and thus to establish the view that the animal receives ready formed by the plant the materials which it requires for its nutrition. Hence many of the analytical investigations of that period had the same aim. In France the question was studied by Dumas and Cahours, who, in 1843, published an extensive series of researches upon this subject. Their numerous analytical determinations led them to the following conclusions:—The albumin of all animals has the same composition; vegetal albumin differs from animal by the existence in it of free alkali; the caseïn in the milk of herbivorous animals has very nearly the same composition as albumin; that of human milk differing from the last in some of its properties, is likewise of the same composition. Ox blood and flour contain a substance absolutely identical with the caseïn of milk. The different varieties of caseïn are isomeric with albumin. Legumin, the neutral nitrogenous principle of leguminous plants is not, as asserted by others, identical with albumin, although convertible by chlorhydric acid into an albumin-like body. The fibrin of blood, when treated with chlorhydric acid, yields a product identical in composition with albumin and caseïn, and therefore exhibits, when submitted to the action of gastric juice, the same behaviour as the two last-named substances.

Closely connected with the researches just noticed, is the comparative examination of the milk of several animals. Dumas shows that sugar, invariably present in the milk of herbivorous, and absent in that of carnivorous, animals, may be made to appear in the milk of the latter by changing their diet. No sugar could be found in the milk of dogs when exclusively feeding upon

meat, but when bread, or other substance containing starch, was substituted for the meat, the generation of sugar was easily traced.

It should not, however, be left unmentioned that in consequence of experiments performed by the more delicate methods at the disposal of modern physiology, the presence of appreciable quantities of sugar in the milk of animals fed exclusively with meat can no longer be doubted.

With the appearance of sugar in the milk the amount of fat and albumin were found by Dumas to diminish.

He also states that dogs' milk when compared with the milk of herbivorous animals, exhibits several discrepancies, being coagulated by heat, for instance. This discrepancy cannot, however, be attributed to any peculiarity of the caseïn, which, indeed, has exactly the same composition and the same properties as that contained in the milk of herbivorous animals.

It was not likely that Dumas would resume his chemico-physiological researches without returning also to the study of blood. The separation of fibrin and albumin from the blood-corpuscles and the preparation of the latter in a state of purity presents considerable difficulty. Berzelius and Müller had shown that, by adding a solution of Glauber's salt to blood which has been freed from fibrin, the blood corpuscles may be filtered off without being altered. Dumas found that even by adopting this process decomposition of the corpuscles not unfrequently ensues, the filtrate often assuming a reddish tint. This inconvenience may, however, be entirely obviated by passing, during filtration, a current of air through the liquid, and thus placing the corpuscles in the same condition in which they exist in arterial blood. This behaviour would indicate that the corpuscles are endowed with a sort of respiration which is prejudiced by the membrane inclosing them being injured. In studying the corpuscles great care must, therefore, be taken to preserve them intact. According to Dumas, many salts, such as potassium, sodium, and ammonium chlorate, are apt to injure them, whilst other salts, like sodium sulphate and phosphate, Rochelle salt, &c., are without action. From more recent experiments, however, it would appear that, in addition to the nature of the salts, the state of concentration of their solution plays an important part in these reactions. The intact condition of the blood-corpuscles may be readily ascertained by exposing them to the action of oxygen, when they assume the reddish coloration which characterises arterial blood.

Chemical analysis of blood-corpuscles led Dumas to classify them with proteïc compounds, the excess of carbon beyond that contained in albumin and caseïn being attributed by him to the colouring-matter of blood which is present in them. Recent experiments, it is well known, leave no doubt that the blood-corpuscles are not a unitary substance, containing as they do lecithin, cholesterin, and inorganic salts, in addition to the protëides (hemoglobin and albumin) of which they are composed.

While engaged in researches on physiological chemistry, Dumas was naturally led to inquire into the formation of fat, a question which was at that time freely discussed among chemists. The majority, and foremost among them Dumas, Boussingault, and Payen, were of opinion that the fat accumulating in the animal body, exactly like the nitrogenous constituents, was supplied ready-formed by the plant, and a series of experiments performed by them was apparently in favour of that opinion. Liebig, on the other hand, contended that the animal organism was endowed with the faculty of converting the carbohydrates of the food consumed, more especially starch and sugar, into fat.

An appeal to experiment has, as is well known, decided the controversy in favour of Liebig. The French chemists, it is true, believed themselves to have showed that plants contained enough fat-like bodies—substances soluble in ether—to account for the fat of animals consuming them. On resuming the inquiry Liebig showed, however, that although vegetal food contained much more fat than had been hitherto believed, its amount was altogether insufficient to explain the enormous quantities of fat deposited in fattened geese and pigs fed exclusively upon vegetal food. In the presence of this conflicting evidence Dumas thought that a solution of the difficulty might be arrived at by submitting the origin of bees'-wax to a more searching examination than it had hitherto received.

Brodie's splendid researches had just unveiled the nature of bees'-wax, proving it to consist exclusively of aliphatic bodies—cerotic acid and myricyl palmitate—and the question arose: From what material does the bee elaborate those substances? In conjunction with his friend Milne Edwards, Dumas answered this question. They showed that bees, though feeding exclusively upon honey, did not lose the power of producing wax. It is true the opinion originally expressed by Swammerdam, Maraldi, and Réaumur, that bees extracted the wax from plants along with the food they gathered, had already become doubtful by the investigations of Huber, and subsequently of Gundelach. But the results of these inquirers had not been altogether decisive, inasmuch as they had omitted to determine the quantity of wax contained in the honey, as well as the amount of fatty substances which were present in the bees experimented upon. When these quantities were deducted from the amount of wax produced there remained a very large surplus, the formation of which could only be accounted for by admitting the conversion of sugar into wax within the bodies of the bees. It is not uninteresting to remember that almost simultaneously with Dumas and Milne-Edwards's inquiry, another most striking demonstration of the convertibility of sugar into fat was furnished by Pelouze, who proved that sugar fermenting under the influence of caseïn is readily transformed into butyric acid.

There is a last extensive inquiry we must mention before taking leave of Dumas's experimental labours. We allude to his researches on alcoholic fermentation, published in 1872.

As is well known, four explanations have been suggested of the phenomenon.

1. The physiological theory which regards fermentation as the consequence of the life of the cells of the ferment and as resulting from the functions of those organisms.

2. The theory which attributes the destruction of the sugar to the action of the liquid contained in the cells and exuding into the saccharine solution.

3. The theory of Berzelius, who considers fermentation as produced by catalytic forces, *i.e.*, by contact action.

4. The theory of Liebig, who looks upon it as a chemical decomposition produced by the influence which is exerted by the ferment whilst it undergoes putrefaction.

We must be satisfied by merely stating the conclusions to which Dumas was led by his experiments.

As regards Liebig's opinion, it is contradicted by the following facts :—

Chemical actions excited in saccharine liquids are unable to convert sugar into alcohol and carbonic acid. The movements produced by fermentation itself are not transmitted to sensible distances through aqueous, oily, or metallic liquids, or through thin membranes; in superimposed liquids they do not even pass from one layer to another.

Again, the view of Berzelius cannot be maintained in the presence of the fact that, if certain salts are present, sugar, ferment, and water are capable of remaining in contact with one another without fermentation taking place.

Fermentation in its simplest form, namely, that which occurs when sugar, water, and ferment only are present, constitutes a phenomenon which, owing to the innumerable centres of attraction determining it, can be regulated and measured like an ordinary chemical reaction. Its duration is exactly proportionate to the quantity of sugar present in the liquid. It proceeds more slowly in the dark and *in vacuo*. It gives rise to phenomena, not of oxidation, but of hydrogenation; sulphur in fermenting liquids is converted into sulphuretted hydrogen. Neutral gases exert no influence on fermentation. The action of acids, bases, and salts upon ferments is accelerating, retarding, disturbing, or destructive; but the cases in which acceleration occurs are somewhat rare. Very dilute acids in moderate quantities do not affect fermentation; very dilute alkalies, even in moderate proportions, retard fermentation; in larger proportions they suppress it. Alkaline carbonates, unless very largely present, do not hinder fermentation. The carbonates of the alkaline earths do not interfere with it. The greater number of salts are without effect, but there are some, like potassium silicate, and sodium borate, which coagulate the ferment (yeast), and thus entirely stop fermentation.

Alcoholic fermentation, according to Dumas's experiments, may be studied like any other chemical phenomenon. Chemical agents, though unable to produce it, are at all events capable of modifying its results. It deserves, however, to be noticed that those who attribute it to the action of an organism, yeast, for instance, may nevertheless freely admit that the conversion of sugar into alcohol and carbonic acid is a purely chemical phenomenon, but a chemical phenomenon which is caused by vital, and not exclusively by chemical and physical forces.

The facts enumerated were all established by the study of beer-yeast, which may be looked upon as the type of ferments capable of reproduction when the fermenting liquid offers the necessary conditions. But there are ferments which are utterly destroyed whilst doing their work, of which class diastase is a good representative. Dumas also communicated a few very interesting observations regarding this second group of ferments. He found that borax destroys the fermentative power, not only of yeast, but also of diastase, synaptase, and even myrosine, the effect being most likely due to the solvent action it possesses for organic bodies. Thus he pointed out that the pellicle of the egg, for instance, is readily soluble in a moderately concentrated borax solution.

The experiments on fermentation are among the last which Dumas has published. The important paper on the occlusion of oxygen in silver, communicated to the Institute only last year (1878), has been already briefly noticed.

In the preceding pages we have endeavoured to give a sketch of the more important of Dumas's numerous and varied researches in chemistry and physiology, and to trace their influence on the progress of science. It need scarcely be pointed out that there are many minor investigations which have not been enumerated; but we may at least place on record some of the subjects of which they treat.

The often discussed question whether chlorides dissolve as such or in the form of chlorhydrates, the causes of isomerism, the evolution of light during the disintegration of fused boracic acid, the disengagement of gas from rock-salt decrepitating in contact with water, the determination of specific heat, the composition of Cadet's fuming liquor (alcarsin) for which he proposed the formula subsequently corroborated by Bunsen's researches, the chlorides of sulphur, the compounds of phosphorus and more especially those with hydrogen, the behaviour of liquid nitrous oxide, the several varieties of fulminating gold produced by the action of ammonia on terchloride and teroxide of gold, the compounds of chloride of tin and sulphur, the composition of the most important varieties of glass occurring in commerce, the analysis of minium, the preparation of calcium by the action of sodium on iodide of calcium, which afforded Dumas an opportunity of pointing out the importance of working in closed vessels under pressure, and lastly, in conjunction with Grellet, the treatment of iron ores, and with Persoz, the composition of wall-pictures executed in the thirteenth century, such are some of the subjects in general and mineral chemistry which have in the course of time engrossed his attention.

Among the researches carried out within the domain of organic chemistry, experiments on the composition of the organic alkaloids, performed along with Pelletier at the very outset of his career, the analysis of cerosin, of naphthalin and paranaphthalin, of mustard oil, of orcin and orceïn, of hippuric and sebacic acids, the abnormal vapour-density of acetic acid, the products of the dry distillation of resin, retinapthen, and retinolen, the constitution of some of the more important organic acids such as tartaric and citric, and last, not least, his long-continued researches on vegetal substances connected with camphor and on some essential oils, may in conclusion be still referred to.

No one, who had not, like Dumas, made the most of the gold dust of time could have attempted the diversity of labours reflected from the picture we have endeavoured to delineate. Dumas never stops working; if it be not in the laboratory, it is elsewhere. Even when travelling for health or pleasure his mind is bent on chemical observation, and many a flower, gathered on the roadside, so to speak, rewards exertions uninterruptedly devoted to the cause of science.

In 1839 Dumas travelled in Switzerland. When at Berne he visited M. Pagenstecher, an apothecary of that town, who devoted his leisure hours to the investigation of vegetal substances. Amongst other compounds extracted from plants M. Pagenstecher showed him an essential oil obtained by distilling with steam the flowers of *Spiræa ulmaria*, the well-known meadowsweet. The characteristic odour of this oil at once reminded Dumas of hydride of salicyl, then just discovered in his laboratory by Piria, when studying the action of potassic bichromate on salicin. By a few decisive experiments Dumas had the good fortune to prove the absolute identity of the natural and artificial product, and thus to associate his name with the early history of salicylic aldehyde, which by numerous subsequent researches, by its occurrence in the larvæ of *Chrysomela populi*, by its prepara-

tion from phenol and chloroform, by its transformation into cumarin, &c., has long since become one of the most interesting compounds of organic chemistry.

At a later period (in 1846) a visit to Aix les Bains in Savoy afforded him an opportunity of witnessing the transformation of sulphuretted hydrogen into sulphuric acid under very peculiar circumstances. He found the calcareous walls of the bath-rooms coated with a thin film of minute crystals of gypsum, the formation of which was obviously due to the sulphuretted emanations from the hot water. But where was the oxidation of the sulphuretted hydrogen accomplished? The air of the room did not contain a trace of sulphuric acid. Solution of barium chloride could be left for days in contact with this air without exhibiting the slightest turbidity. The combination of sulphuretted hydrogen with oxygen, it could not be doubted, took place on the walls themselves, the porous materials of which acted in this case somewhat like spongy platinum upon a mixture of hydrogen and oxygen. The curtains of the bath-rooms were found to acquire very rapidly an acid reaction, and to yield, when immersed in water, an appreciable quantity of free sulphuric acid to it. Direct experiments proved that, when a mixture of sulphuretted hydrogen, air, and aqueous vapour at a temperature of from 40°–50°, is passed over porous substances, or substances presenting a considerable surface, such as linen for instance, sulphuric acid is rapidly produced. The transformation ensues even to a greater extent at a temperature of from 80° to 90°. Formation of sulphurous acid and separation of sulphur are not observed under these circumstances.

In drawing this outline of Dumas's labours in experimental and philosophic chemistry the author has often been sorely embarrassed by the narrowness of the frame into which he has had to compress his sketch. Anxious to assign to the illustrious investigator his due position among the great scientific sowers and reapers of our time, he has only been able to spread out a few sheaves in order to show the luxuriant richness of the harvest. The reader who may feel disposed more fully to trace in its manifold ramifications the influence of this master mind on the progress of chemical philosophy is referred to Hermann Kopp's splendid volume, "The Development of Chemistry in Modern Times," which forms part of the great series of historical treatises on science inaugurated by the late King of Bavaria. Kopp's work is not less remarkable for the spirit of inquiry with which the author descends to the very sources of information, and for the lucidity with which he presents the results of his researches, than for the impartiality with which he acknowledges the share contributed by each nation to the progress of chemistry. How often is the towering figure of Dumas to be seen standing out in bold relief amongst those of his eminent contemporaries presented to us on the pages of this volume!

Lucidity of exposition and the graces of style are not necessarily associated with the gift of successfully interrogating nature. It happens but too frequently that the results of admirable inquiries are almost hidden in papers hastily, not to say negligently, written. But no one has ever found fault with Dumas in this respect. Few chemists perhaps have published their researches in a more attractive and lucid form. And the same graceful elegance and perspicuity of style are found in whatever has proceeded from his pen. One might fancy that he takes the same pains whether it is a friendly letter or an elaborate report, a festal oration or a philosophic essay that he is writing; or perhaps, we should rather say, they seem to be all written with the same facility.

The works of Dumas present considerable variety, both as to the subjects discussed and to the form of treatment adopted. There are several elaborate treatises and a great many minor pamphlets. His academical notices, his official documents, his municipal reports, his festal speeches, his opening discourses, his commemoration addresses, his funeral orations are countless. We may be allowed briefly to allude to his more important writings.

Among these his "Traité de Chimie appliquée aux Arts" deserves to be noticed first. This important work, which is dedicated to Baron Thenard, consists of eight volumes, the first of which, as has been already stated, appeared as far back as 1828; the last one was published twenty years later. It is accompanied by a fine Atlas of Plates. The treatise has been translated into several languages, the German edition being by Gottlieb Alexander and Friedrich Engelhart. In the preface the author informs us that the book is founded upon the notes collected for a course of chemical technology extending over three years, which he had to deliver at the Royal Athenæum. And nothing could give a better idea of the time and energy devoted to the preparation of these lectures. The labour of accumulating such a mass of facts must certainly have been enormous, nor could the effort made in disposing them in such luminous order have been less. Indeed we find here the principles of classification which have ever since been retained in chemical technology. After many attempts Dumas adopted four chief groups in which the endless variety of subjects treated of were logically collocated. The first group embraces the non-metallic elements and the important compounds to which they give rise, such as water, the principal acids, ammonia, atmospheric air, the several varieties of carbon and coal, including the processes of heating and lighting. In the second group are described the metals of the alkalies and alkaline earths, as well as the numerous and important compounds which they produce, such as potashes, nitre, soda, lime, alum, &c., together with their applications in the manufacture of gunpowder, in that of cements, and in the allied industries of glass, porcelain, and earthenware. The third group gives a complete history of the ordinary metals, such as iron, copper, lead, zinc, silver, gold, platinum, &c. The extraction of these metals from their ores and their conversion into the various alloys employed in the arts and manufactures constitute prominent features of this group, although the metallic compounds of minor importance are by no means neglected. In the fourth group, lastly, the author unites all the products of organic nature with their countless applications; bleaching and dyeing, cellulose, starch, sugar, alcohol, soap, cheese, the manufacture of paper, and the processes of tanning, &c., are treated in succession.

But it is not only this happy classification, nor the accuracy with which so vast a number of details are treated that confers their value on these volumes; the powerful influence the work has exerted upon the progress of chemical technology is much more due to the scientific spirit manifested in its pages. It is by this scientific spirit, ennobling operations which had hitherto appeared menial and trade-like, that Dumas has sealed the pledge of that brotherhood between industry and science, the feeling of which has ever since become more and more deeply rooted in the minds of chemists.

"Some people," says Dumas in his preface, "will find that I have given far too many details of pure chemistry, and that I was wrong in looking at manufacturing questions from a theoretic point of view; that at all events I should have avoided representing industrial processes in atomic equations. My answer to them is, that the book is addressed to the student and not to the finished manufacturer, that my aim has been not to describe the practice of technical processes, but to elucidate their theory, and that scientific explanations which startle manufacturers of a certain age, will prove playwork for their children, when they have learnt in their colleges a little more of mathematics, and a little less of

Latin, a little more of physics and chemistry and a little less of Greek."

At a later period, about ten years after the first volume of the "Traité de Chimie appliquée aux Arts" had appeared, Dumas's celebrated "Leçons sur la Philosophie chimique" were published. In these eleven lectures, which, during the summer of 1836, were delivered in the College of France, he traces the development of chemical doctrines from remotest antiquity up to the time at which the course was given. Indeed the last lecture is devoted to the generation of electricity by chemical action, to the chemical effects of the battery, to the ever-memorable experiments of Sir Humphry Davy, and to the electro-chemical theory he founded thereon, as well as to the electro-chemical theories of Ampère and Berzelius; while it concludes with a survey of Faraday's electrolytical researches. The record of these remarkable lectures we owe to M. Bineau, at a later period Professor of Chemistry in the Faculty of Lyons, who obtained Dumas's permission to publish the copious notes he had taken; the accuracy of the record being specially recognised by the author. The work has also appeared in several translations, the German one being by Prof. Rammelsberg, the eminent successor of Heinrich Rose in the University of Berlin. The original was reprinted in 1878, of course unchanged. The lectures on chemical philosophy incontestably prove that with the elegance and lucidity of the writer, Dumas in a most conspicuous manner unites the eloquence and power of the speaker. How delighted are we to listen to the charming harmony of these euphonious sentences! How ready to submit to the convincing power of the ideas they convey, irresistible by their close logical concatenation! Every lecture teems with passages which the reader peruses over and over again, in the hope of retaining them by heart. Hear how he delineates the method peculiar to chemical inquiry:—"And what is this method, which, old as our science itself, is now what it was in the days of its infancy? It is an absolute belief in the testimony of the senses, a boundless confidence in experiment, a blind submission to the supreme authority of facts. Chemists, ancient or modern, desire to see with the eyes of the body, before using the eyes of the mind, they think it right to make theories for facts established, but not to seek facts for theories preconceived." I have quoted these lines not only as affording good evidence of the style of Dumas's lectures, but also as containing, so to speak, a confession of faith from which he has never swerved throughout the long course of his experimental inquiries. And how happily does he record the development of chemical doctrines, interweaving now and then short biographical sketches of their authors? The comic element is but very sparingly introduced, although the history of the alchemists presents a good many tempting opportunities, but nothing could surpass the taste and humour with which the anecdotes admitted are told. On the other hand his language becomes solemn and impressive when he recalls the catastrophes of which some of the most ardent chemical inquirers have been the victims, whether he describes the martyrdom of Raymundus Lullus, or the persecutions of the Protestant Nicolas Lémery, or the political and religious commotions which compelled Priestley to leave his native country, or lastly, the never-to-be-sufficiently-lamented death of Lavoisier. Truly, since the days of Archimedes, the history of science records no more tragic event than the cruel fate of Lavoisier. It has been and ever will be the subject of universal sorrow, and never has this sorrow been expressed in more affecting terms than by Dumas in the lecture which he delivered on the forty-second anniversary of the event. Let me quote some of these impressive lines:—

". . . It was at that time that Lavoisier had conceived the idea of publishing a collection of his memoirs. If this work had been finished we should have been able to survey at one glance the splendid series of his inquiries, and my task would have been more easily accomplished. But whilst preparing this publication he was struck down by an atrocious death and the collection remains incomplete, the most touching monument presented by the history of science. Nothing is more painful than to glance at this work, of which the second volume only is finished, whilst the first and third, in process of printing, appear to be cut off by the same axe which laid their author low. The sentence is broken off at the place where the pen stopped as the executioner laid hold of him. Nothing, I repeat, can possibly excite more acute emotion, nothing a deeper sense of the tragic element in the fate of man, than the sight of these doleful pages, the continuation of which is hidden by a veil of blood."

Among the numerous writings of Dumas none perhaps has found a more cordial reception in wide-spread circles than the lecture with which on August 20, 1841, he concluded his course of chemistry in the Medical School of Paris. This lecture is published under the title "Essai de Statique chimique des Êtres organisés. Par MM. Dumas et Boussingault," and gives in a simple form the principal features of the life of plants and animals considered from a chemical point of view, presenting a most eloquent *résumé* of the chemical and physiological researches, in which the two friends, either individually or jointly, had been engaged for many years. The views brought forward by the authors have long since become generally received truths. It is, therefore, more especially the elegance of the form which we admire to-day, whilst at the time the essay appeared it was perhaps not so much the style as the novelty of the views themselves that fascinated the reader. No wonder that within a very short time the pamphlet was translated into nearly all modern languages. Even the programme of the lecture presented the subject in an aspect then perfectly new.

THE ANIMAL acts as an apparatus of *combustion*—		THE PLANT acts as an apparatus of *reduction*—	
burns	carbon, hydrogen, ammonia;	*reduces*	carbon, hydrogen, ammonia;
expires	carbonic acid, water, ammonia, nitrogen;	*fixes*	carbonic acid, water, ammonia, nitrogen;
consumes	oxygen, neutral nitrogenous substances, fat, starch, sugar, gum;	*produces*	oxygen, neutral nitrogenous substances, fat, starch, sugar, gum;
produces	heat, electricity;	*absorbs* *withdraws*	heat; electricity;
restores	its elements to air and earth;	*borrows*	its elements from air and earth;
transforms	organic matter into mineral matter;	*transforms*	mineral matter into organic matter.

The lecturer realises this startling programme with the utmost simplicity. We shall quote only the concluding passages of the admirable discourse:—

"If we consider the primitive atmosphere of our globe, we have to admit that it exists to-day in three different forms.

"One part constitutes our present atmosphere, a second part exists in the form of plants, a third in the form of animals.

"Between these three divisions a continual exchange takes place. At every moment matter descends from the

air into the plants, passes from them to the animals, by which in turn it is restored to the air.

"It is in the green plant that the great laboratory of organic chemistry is established. It is in the plant that carbon, hydrogen, and nitrogen are gradually converted into the most complex organic substances.

"The force required to perform this work the plant receives from the sun in the form of heat and chemical rays.

"The animal assimilating the organic substances elaborated within the plant gradually alters and ultimately destroys them. Within its vessels and tissues new organic bodies may be generated, but these are more simple in construction and more closely allied to mineral matter than those it has received.

"The animal thus gradually changes the organic bodies slowly elaborated by the plant, transforming them into carbonic acid, water, nitrogen, and ammonia, in which state they return into the atmosphere.

"By the combustion and destruction of organic substances the animal produces heat which radiates from its body into space and thus replaces the heat absorbed by the plant.

"Thus all that the air gives to the plant, the plant cedes to the animal, and the animal returns to the air;—eternal circulation, in which life rises and passes away, but matter only changes place.

"The crude matter of the air is gradually organised by the plant, to officiate unchanged in the animal, and to serve ultimately as an instrument of thought; till vanquished as it were and broken by the supreme effort, it returns in its primitive condition to the grand stores from which it came."

The publication of this lecture gave rise to a dispute between Dumas and Liebig regarding the priority of the ideas propounded therein. The great German chemist having but a year previously, in 1840, published his celebrated work, "Organic Chemistry in its Application to Agriculture and Physiology," had been naturally led to investigations of a similar order concerning the chemical phenomena of animal life, and was then actually preparing his "Chemistry Applied to Animal Physiology." Liebig, no doubt, had freely stated the results of his researches in lectures delivered long before the publication of Dumas and Boussingault's pamphlet; but there is not a shadow of proof that Dumas was influenced by inquiries which at the time were not published. The accusations, it cannot be denied, rather hastily hazarded by Liebig, could not but cause a temporary estrangement between the two great chemists. Fortunately it was of only short duration, and left, as we already have had occasion to learn from their own mouths, no bitterness in their minds. Nor was there any cause for such estrangement. Divine truth is often revealed simultaneously to two different minds, and the unbiased reader of to-day no longer doubts that the conceptions which formed the subject of dispute were independently arrived at by both inquirers. And we are all the more confirmed in this view when we learn that documents have since been found which unmistakably prove that as far back as 1792 Lavoisier was acquainted with the mutual relation presented by the phenomena of vegetal and animal life. We may be permitted to refer somewhat more in detail to this interesting document, since we owe its publication to Dumas, who communicated it to the Chemical Society of Paris.

We have had occasion to allude in Dumas's own words to the unfinished state in which the edition of Lavoisier's work was left by his untimely death. For many years it had been Dumas's desire to pay the debt of gratitude which the world owes to Lavoisier, by publishing a monumental edition of his writings. Of this desire even his lectures on chemical philosophy in 1836 give unmistakable evidence, and between 1843 and 1846 we find him in active correspondence upon the subject with M. Villemain, then Minister of Public Instruction, and M. Léon de Chazelles, the representative of Lavoisier's family. At their meeting on August 28, 1843, the Academy nominated a committee, consisting of Arago, Babinet, Balard, Becquerel, Chevreul, Despretz, Duhamel, Gay-Lussac, Pelouze, Pouillet, Thenard, and Dumas to inquire into the best mode of publishing the works of Lavoisier, and on July 6, 1846, Dumas read the report of the Commission recommending the Minister of Public Instruction to apply to the Chambers for the necessary funds, a report which was adopted by the Academy. Nevertheless it was only on February 4, 1861, that M. Rouland, then Minister, finally decided on the publication, which by a decree of the same date he intrusted to Dumas. But if the preliminaries had been long and tedious, the publication, for which all the necessary preparations had been made in the mean time, now proceeded with remarkable celerity, so that eighteen months later, on September 29, 1862, Dumas was enabled to announce to the Academy the completion of one of the three splendid quarto volumes in which the work was to appear. The volume contains the text of Lavoisier's memoirs, and the editor feels a legitimate pride in unfolding in all its splendour the philosophic wealth of this treasury of observation. By comparing the state of knowledge which the world possessed when the volume opens with that it had acquired when it closes he conveys an idea of the services which the genius of Lavoisier has rendered to mankind, and we are impressed with the conviction that more light has emanated from this one investigator than from whole generations of chemists. The publication of Lavoisier's works, as might have been expected, gave rise to a general search in the public libraries of France, and more especially to a careful examination of the papers still in the possession of his family. Among the latter Dumas discovered the interesting document to which we have alluded. It is entirely written in Lavoisier's own handwriting, and seems to have been the programme or the draft of a programme for prizes to be instituted by the Academy. We shall quote only the commencement of the paper, which shows how clearly the relation of the animal and vegetal kingdoms, and the contrast of the conditions of life of plants and animals were appreciated by Lavoisier more than half a century before those truths were generally admitted.

"Plants derive the materials necessary for their formation from the air which surrounds them, from the water, and in general from the mineral kingdom.

"Animals feed on plants or other animals fed by plants so that the substances composing them are in the last instance always drawn from the air and the mineral kingdom.

"On the other hand fermentation, putrefaction, and combustion continually restore to the air and the mineral kingdom the principles borrowed from them by plants and animals.

"By what processes is it that nature establishes this marvellous circulation between the two kingdoms? How does it generate combustible, fermentable, and putrescible substances by the aid of compounds possessing none of those properties? These are impenetrable mysteries. *We perceive, however, that since combustion and putrefaction are the means employed by nature for restoring to the mineral kingdom the materials previously derived from it, for the purpose of forming plants and animals, vegetation and animalisation must be looked upon as operations inverse to combustion and putrefaction.*"

We have still to glance at the important series of commemoration addresses which Dumas has delivered on many of his departed friends and colleagues. Each one of these addresses, which collected would fill an imposing volume, is a work of art we are never tired of contemplating; each one attains its end by giving a life-like portrait of the person commemorated, a portrait which

remains indelibly stamped on our memory. We know not which to admire most, the conciseness which excludes all that is non-essential from the sketch, or the poetic inspiration which fires the monumental style and throws upon the forms it pictures the light of an ideal conception. Nor are these addresses wanting in numerous interesting particulars which, drawn from the author's own personal intercourse with his heroes, give a life-like colouring to his portraits. Truly astonishing is the range of knowledge displayed by Dumas in these orations. He seems to be equally at home in all departments of science. Achievements in chemistry and physics are by no means exclusively discussed; botany, physiology, geology, astronomy, and even historical research, are in turn brought under consideration; and notwithstanding this great variety in the branches of science treated of, the reader or hearer of such an address receives not merely an idea of the life-work of the person celebrated, but also a picture, drawn in bold outline, of the contemporary development of his special department of science. Often, too, will the orator express himself on questions of the day, and aid their solution by throwing the weight of his word into the scale.

The first of these commemoration addresses—on the young, but already famous, surgeon, Auguste Bérard—was delivered as far back as 1846, in the public sitting of the medical faculty of Paris; and in reading it one might well believe that its author was a professional surgeon.

For chemists, certainly, one of the most interesting of these orations is that on Jules Pelouze, which we have already had occasion to refer to. What charming details does it give of the modest beginnings of the man—his first meeting with Gay-Lussac in a suburban vehicle between Charenton and Paris, his splendid quarters in the rue Copeau, where he had to open the window for room to pull on his coat, his healthy dinner of bread and water, a *régime* which, as he used to say, keeps the head clear! What a contrast to the princely mansion on the Quai de Conti, where so many of his fellow-workers afterwards enjoyed his noble hospitality! Pelouze was one of the first chemists in France who afforded to a considerable number of students the opportunity of working practically in his laboratory; and this circumstance gives Dumas occasion to speak a powerful word for the institution of public laboratories, such as Germany, led by Liebig, already possessed in all its universities.

"It is no longer doubted that the laboratories where chemists receive their training are public institutions worthy of encouragement by the State, and that the teachers who devote their energy and talents to superintending them deserve the recognition of their country. It is not long ago, however, since public opinion, loth to acknowledge their efforts, viewed them with no favourable eye. It seemed natural enough that a painter or architect should be surrounded in his studio by pupils sharing his work, and should form a school. But this ambition ceased to be respected when manifested by a chemist. Were not teachers so lavish of their instruction, moved by interest or by pride rather than by the love of truth? Were not the slowly elaborated results of solitary investigation to be preferred to the hurried communications so frequently ventured upon through the feverish excitement of working in company? Were fruits hastily ripened by the forced cultivation of the hot-house likely to be sweeter than those grown in the open air and gathered in their season? Did not these proffered facilities, these subjects of research suggested by the master and discussed amongst fellow-students relax personal effort, and was not their tendency to develop pretensions rather than to create or discover talent? Experience has given its answer. These mutual schools of chemistry, where professors and students interrogate nature together, have accomplished in fifty years the work of several centuries. They spread over the surface of the globe chemists animated by noble ambitions, new labourers whose intellectual work promises to restore to the earth the fecundity exhausted by the labour of the hand of man."

Not less interesting are the memorial speeches on Isidore Geoffroy Saint-Hilaire, the anatomist, and Arthur Auguste De la Rive, the physical philosopher. With both men Dumas was on terms of intimate friendship, more especially with the latter, whom he had known in early youth and with whom he had ever since kept up a constant correspondence. Auguste De la Rive was a son of that Gaspard De la Rive in whom, as we have already seen, Dumas had found a fatherly friend and patron during his residence at Geneva. On this occasion many youthful recollections are, as might be expected, revived in Dumas's mind. We learn, for instance, that he was present at the memorable verification of Oersted's fundamental experiment which took place in the laboratory of Gaspard De la Rive, more than half a century ago, and on which Arago, who was one of the spectators, made the following report to the Academy on his return to Paris:—"Prof. De la Rive, of Geneva, to whom we owe the discovery of some most interesting phenomena brought to light by his powerful batteries, was good enough to allow me to witness the repetition of Oersted's great experiment carried out by him in the presence of MM. Prévost, Pictet, Th. de Saussure, Marcet, De Candolle, &c., and I have thus had an opportunity of convincing myself of the correctness of the results arrived at by the Danish investigator." "As my name is not mentioned," adds Dumas jocosely, "in Arago's report, I must of course assume that I figure among the &c." Returning from the father to the son the orator then exhibits to his hearers in the most attractive manner the different phases of his life and calling, exciting their liveliest interest in the numerous problems his hero set himself to solve, such as the investigation of the *Aurora Borealis* and of the after-glow of the Alps.

Specially deserving of mention, moreover, is the beautiful oration on the two Brongniarts—Alexandre, the great geologist, and Adolphe, the celebrated botanist. As already remarked, Dumas had married into their family, and was thus from his daily intercourse with these men, happily able to rescue from oblivion many interesting particulars of the relation in which they stood to their contemporaries. The youth of Alexandre Brongniart fell in the period of Lavoisier's great discoveries, which could not fail to have their effect upon the young man's susceptible spirit. When but sixteen years of age he attempted to diffuse the new doctrine to the best of his ability, and of this time Dumas relates a charming anecdote, which we cannot do better than give in his own words:—

"In an outhouse attached to the residence then occupied by his father as architect to the Hôtel des Invalides, he had fitted up a lecture-room. One day, Lavoisier, who had long been on terms of intimacy with the family of the extemporised professor, finding the door open, entered and seated himself modestly amongst the scholars. His opinions, expounded with the ardour of conviction by the voice of youth, were warmly applauded by pupils, who, having nothing to forget, were easily impressed by the light conveyed. Perhaps he saw at that moment better than when in the society of his ever-confused and hesitating colleagues, that, if the old chemistry was not yet vanquished, the future lay at the feet of the new. He graciously congratulated young Brongniart, who, taken aback at his own temerity, was yet glad to have been ignorant that he had been expounding the new theory of chemistry in the presence of its immortal author, the object of his worship."

But, far from dealing exclusively with the details of the life of the two Brongniarts, the address also accomplishes with rare success the much more difficult task of giving a

popular account of the results of their studies. Listen, for example, to the comparison which Dumas draws between the fields of investigation of Cuvier and Brongniart, whose labours so often meet and supplement one another:—

"After having reconstructed twenty-three species of fossil quadrupeds now extinct, Cuvier did not hesitate to conclude that, in all countries, bones were to be found underground almost always different from those of the animals which to-day inhabit the surface. But the bones of such large animals as required an extended domain for the support of life, are naturally rare; a whole quarry might be searched without our coming upon the least trace of them, and even if their presence is apt to characterise the soil in which they are found, it cannot furnish the means of practically determining its geological date.

"Brongniart, more fortunate in this respect, studies all the known species of fossil shells and compares them with those of the present day. Certain species live in salt water, others in fresh, and still others in brackish water, and, from their presence, the conditions may be inferred under which the sediment containing them was formed. The remains of those inferior creatures—small, and sometimes microscopic—which needed but little nourishment, are met with in unlimited quantities; whole soils are formed of their *débris*, and are thus in truth the ashes of an extinct life. As regards them, the surface of the globe is a vast cemetery, and when the geologist questions the soil, it is no longer from some gigantic bones scattered here and there, but from the very tomb of those wide-spread dwellers in the ancient world, that the reply arises."

There is another and last commemoration address to be mentioned which Dumas delivered but a few months ago. It is devoted to the memory of Antoine Jerome Balard. His record of the life of this man, who, from the simplicity of his habits, and from his utter disregard, bordering on contempt, of wealth and comfort, appears to us almost a modern Diogenes, will ever be looked upon as a touching monument of the life-long friendship by which the two academicians were united. "Younger than myself," says Dumas, "Balard lectured in my place at the Sorbonne He was my successor as inspector-general of the University, and I had cherished the hope that he would one day pay to my memory the tribute of justice and affection which to-day I am startled at having to render to his. Fellow countrymen, almost of equal age, and beginning scientific life under the same conditions—these circumstances were the prelude to those forty years of intimate friendship which united us, and the recollection of which swells my heart at this moment."

Balard's life, like those of the majority of scientific men, was of a peaceful and domestic kind—no dramatic events, no stirring incidents—and yet how fascinating is the narrative of these plain occurrences of his humble boyhood, of the aspirations of his youth, of the assiduous work of his manhood, of the noble dignity of his age. Again, no one else could have given that most interesting history of the discovery of bromine, as we receive it from the mouth of Balard's early friend, no one could have more eloquently traced the influence of this discovery on the development of chemical philosophy, on photography, on pathology, on the progress of organic chemistry, and even on the latest evolution of the tinctorial industries. And how strange the contrast between the remarkable discovery of his early youth, so happily conceived and carried through, and the unremitting and painful efforts of his riper years, in the hope of attaining results which appeared to recede when just within reach, and which by a strange fatality had almost lost their value when at last actually laid hold of. It is well known that Balard had conceived the idea of unlocking the inexhaustible stores of the ocean, in the hope of endowing the industry of the alkalies with a cheap supply of sulphate of sodium and of potassium salts, and that when by endless experiments he had succeeded in establishing the conditions under which these salts can be made to crystallise from sea water, the substitution of iron pyrites for Sicilian sulphur in the manufacture of sulphuric acid on the one hand, and the discovery of immense deposits of potassium minerals overhanging the rock salt of Stassfurt on the other, reduced the prices of those salts to such an extent as to render their extraction from the ocean almost impossible. Dumas gives a most interesting account of the stoic fortitude with which Balard, satisfied with the philosophic solution of the grand problem, submitted to the double disappointment caused by the industrial failure of his processes.

Nor when Dumas's commemoration addresses are enumerated can his beautiful Faraday lecture be left unnoticed. It is well known that soon after Faraday's death in 1867 the Council of the Chemical Society of London organised a periodical celebration of his life and labour by instituting a triennial prize to be conferred upon scientific men of all countries whom they proposed from time to time to invite for the purpose of rendering homage to the memory of the great experimental inquirer of our century.

It was Dumas who on June 17, 1869, opened this cycle of commemoration addresses by delivering a most eloquent lecture in the theatre of the Royal Institution, where the voice of Faraday himself had been so often heard. We cannot hope to give here an adequate idea of the grand conception of this discourse in which the speaker set before his hearers the influence which the labours of Faraday exerted upon the progress of mankind, but we may be allowed to quote at all events some of the introductory passages of the lecture,[1] which reflect the sentiments of friendship and admiration entertained by Dumas for the great British physicist:—

"You have desired that the memory of Faraday should be handed down to posterity; you have summoned together men of science all to celebrate, in a solemn manner, his great and beneficial labours; and, calling upon France to take the lead in this solemnity, you have chosen me to be his panegyrist, no doubt on account of the long and constant friendship with which I was honoured by Faraday.

"I am the bearer of the acknowledgments of the scientific men of France, as well as my own. My country—I am proud to say it—can offer representatives of science much more worthy of your approbation; but I know no one, at least, who feels more intimately the sentiments of profound gratitude for the noble welcome which England has accorded for so long a time, nor do I know one who bears so sincere a veneration for Faraday.

"The name of your illustrious fellow-countryman is not one which any single nation can claim as its exclusive property; his labours and discoveries are as widely recognised in France, in Germany, and in America as in England. Faraday belongs to the whole world. There is not a spot on this earth to which civilisation has penetrated that does not claim the right of participating in the respect and gratitude you entertain for him.

"Faraday was identified with the scientific movement of the first half of this century; he was one of its principal leaders, and drew in his train a whole host of thinkers, engineers, men of enterprise, and capitalists. Ever contemplating the chaste beauties of nature, and searching into her most hidden recesses, this disinterested philosopher, this deep thinker, scattered broadcast on his path the seeds of the most extraordinary and unheard-of results—such are the electric currents of Faraday that bear our messages, furrowing Europe and traversing the Atlantic—such are those lights, rivalling the sun in brilliancy which shine forth from our lighthouses; and it

[1] Reported in *Chemical News*, vol. xx. No. 501, 1.

is even to the gases which he liquefied that hot countries owe the luxury of ice.

"In the pursuit of truth alone he was able to satisfy, as if by accident, the boldest demand of a refined civilisation; and, devoted to the ideal, he sowed the seeds of riches, not for himself, for he despised them, but for the profit of trade, which has gathered the fruits.

"Faraday is the type of the most fortunate and most accomplished of the learned men of our age. His hand, in the execution of his conceptions, kept pace with his mind in designing them; he never wanted boldness when he undertook an experiment, never lacked resources to ensure success, and was full of discretion in interpreting results. His hardihood, which never halted when once he had undertaken a task, and his wariness, which felt its way carefully in adopting a received conclusion, will ever serve as models for the experimentalist."

The commemoration addresses — *éloges historiques*, as they are called in France—on Pelouze, Geoffroy Saint-Hilaire, De la Rive, the two Brongniarts, and Balard, were delivered at the annual public meetings of the Academy of Sciences. Very different was the occasion to which the beautiful oration on Guizot owes its origin. After the death of the distinguished statesman, the French Academy, true to its traditional custom of bestowing its membership on the permanent secretary of the Institute, rendered to Dumas the honour which his predecessors in office, men like Fontenelle, Condorcet, Fourier, Cuvier, and Flourens, had received. It fell, as the rule was, to the new nominee to deliver the memorial address on the departed member whose place he was to fill, and Dumas performed this duty in the public sitting of the French Academy on June 1, 1876, with his wonted mastery of the subject. It is true that he who would describe the life of a man like Guizot has no thankless task before him. For whether he considers the critic who exhibited the creations of Shakespeare in the light of his conceptions; or the historian who opened up new sources of investigation for his science; or the philosopher who sought to discern the ends of Providence in the progress of mankind; or the biographer who could delineate with a few bold touches the greatest physiognomies of modern times; or the master of debate with whom but few could cope; or the statesman whose steady hand long guided his country's destiny, and who, when fortune deserted him, was able, undiscouraged and unembittered, to forget the minister in the man of letters—in every respect has the orator a splendid picture to offer, a picture calculated to excite interest and to awaken sympathy. Still we must not forget that Dumas is here treading foreign ground, that he cannot here command those rich resources which he has in such ready abundance when commenting on achievements in the exact sciences. But when, despite these disadvantages, he is nevertheless able to do full justice to the subject intrusted to him, this success may be taken as a proof of the many-sidedness of his talents.

Essentially different from these commemoration addresses, but not less masterly of their kind, are the numerous orations he has delivered—sometimes in the name of the Academy, sometimes in his capacity as vice-president of the Educational Council—at the funeral obsequies of distinguished men, amongst which those on Élie de Beaumont (1874), on Le Verrier (1877), and on Claude Bernard (1878), may be specially mentioned.

But there are other duties than the delivery of commemoration addresses in store for the academician. Any task imposed upon the Institute in the accomplishment of which chemistry is directly or indirectly concerned, invariably devolves upon Dumas.

The *Comptes Rendus* of the last fifty years contain an endless series of reports addressed to the Academy, which either alone or in conjunction with some of his colleagues, he drew up on a great variety of subjects. Were we to attempt to do full justice to this part of Dumas's work, we should have to ask the reader to accompany us into the most different departments of inquiry; but some idea of its importance may be given by quoting the following illustrations.

It is well known that Nicolas Le Blanc, the inventor of the soda process, never reaped the fruits of his splendid discovery. But the cause of this failure has been very differently stated. A peculiar circumstance gave rise to a minute examination of the case. In 1855 the Marquis de Manoury d'Ectot presented to the Emperor Napoleon a petition from the family of Le Blanc, praying for a tardy recognition by the State of the services their father had rendered to France and to the world at large. On November 17, 1855, the Emperor requested the Academy to inquire into the claims of the petitioners, and the latter naturally referred the matter to the Chemical Section, consisting of Thenard, Chevreul, Pelouze, Regnault, Balard, and Dumas, the latter being, as usual, charged with drawing up the report. This document is so interesting, more especially to chemists, that we cannot deny ourselves the pleasure of giving some account of its contents.

As the Commission had to inquire into events which happened sixty years before, and of which no eye-witness could be summoned, the investigation presented considerable difficulties, and the author of this sketch, who along with Mr. (now Sir William) Grove, and Mr. Warren De La Rue, was requested at the time to trace, if possible, certain documents drawn up in London, had an opportunity of admiring the indomitable energy with which the Commission endeavoured to surmount the obstacles in their path.

We learn from their report the true causes of Le Blanc's misfortunes. In 1789 Nicolas Le Blanc, who held the position of surgeon to the Duke of Orleans (Philippe Égalité), had asked the Duke to advance the money necessary for the establishment of a factory for the conversion of sea-salt into soda. The Duke before complying with this request, had submitted the matter to d'Arcet, then Professor of Chemistry in the Royal College of France, who charged his assistant Dizé with the supervision of the confirmatory experiments. These experiments having proved satisfactory in every respect, an association was formed, called the Société de la Maison-de-Seine, and an agreement was signed before a London notary on February 12, 1790, by the Duke of Orleans, Le Blanc, Dizé, and Henri Shee, who was a financial agent to the Duke, in which the latter promised to advance 200,000 livres tournois for the purpose of carrying out Le Blanc's soda process and Dizé's process of manufacturing white lead, the description of which the inventors agreed to furnish in a sealed letter to be deposited in the hands of a public notary.

This letter, dated March 22, 1790, the Commissioners had had the good fortune to trace, as well as the final Act of Association, dated January 27, 1791, in which the mutual interests of the partners were settled, and lastly, the secret patent (*brevet secret*) which was granted to Le Blanc, on September 28, 1791, by the National Assembly's Committee on Agriculture and Commerce. The latter, given *in extenso* in Dumas's report, is a most remarkable document, for not only does it prove that the soda process arose from Le Blanc's mind perfect and finished, like Minerva from the head of Jupiter, but it also predicted with almost prophetic foresight, the influence the process has exerted on the development of chemical industry.

All preliminaries being thus satisfactorily completed, the Société de la Maison-de-Seine established the first soda factory at La Franciade, near St. Denis, but had scarcely commenced working, when events took place which irretrievably blighted the prospects of the new in-

dustry for years to come. The revolution had arrived at the stage at which the property of the Duke of Orleans was sequestrated, and Le Blanc was thus deprived not only of his financial resources, but even of the works he had just established; and, to complete his misfortune, the army section of the Committee of Public Safety invited the citizens to give up the secret of any process which might prove useful in the defence of the country. As invitations by the Committee of Public Safety did not admit of hesitation on the part of those invited, an account of the process, probably written by Le Blanc himself, was published on the second of Messidor of the year II. (June 20, 1794) by d'Arcet père, Pelletier, and Lelièvre. Dumas's report then dwells at some length on Le Blanc's ever-renewed but unfortunately vain efforts to recover from the blow when the storm had subsided, and on the exertions kindly made on his behalf by friends and corporations, in which connection Chaptal, then minister, and the Société d'Encouragement just founded at that time, deserve mention. These exertions, we are sorry to learn, were of no avail, and the inventor of a process which has been one of the principal levers for the advancement of the chemical arts, and certainly the source of wealth for individuals and nations, died, in 1806, broken-hearted from disappointment and distress.

The conclusions at which, after a searching investigation, the chemical section of the Academy arrived, are thus given by Dumas:—

1. The important discovery of the process by which sea-salt is converted into soda, is entirely due to Le Blanc.

2. Dizé was only associated with Le Blanc in researches the object of which was to ascertain the best proportions of the materials to be employed, and in establishing the factory of St. Denis.

3. If, therefore, as Le Blanc's family desires, just homage is to be done to the discoverer of artificial soda, it is due to the memory of Le Blanc.

4. If there was, moreover, an indemnity to be granted for the losses incurred by the sequestration of the factory of St. Denis and by the subsequent publication and nullification of the patent, the Section, without wishing to forestall the decisions of a more competent authority, think that this indemnity should be divided between the representatives of the several associates, in accordance with the terms of the Treaty of Association of January 27, 1791.

The conclusions of the report were adopted by the Academy at their meeting on March 31, 1856.

In accordance with these conclusions several compensations were bestowed by the Government upon those most in need of them, but Le Blanc's great discovery, we learn with regret, has not yet found the adequate public recognition so eloquently advocated by the elaborate report of the Academy.

Among the numerous reports on questions of national economy, those on the diseases of the silkworm and on the devastations of the Phylloxera, addressed by Dumas at different times to the Academy deserve particularly to be noticed. When it is remembered that the value of the annual silk production of the world amounts to 1,000 million francs, and that the normal contribution to this value made by France, though only one-third that of Italy, exceeds 100 million francs, it will be understood that a fall of the French silk production from 26 million kilos, which it was in 1853, to $7\frac{1}{2}$ million kilos in 1856, could not but be looked upon as a national calamity. Nor is it surprising that a paper on the improvement of the breed of silkworms, presented early in 1857 to the Academy by M. André-Jean, excited general interest, and that the Academy charged a commission, consisting of the Marshal Vaillant, Milne Edwards, Combes, Peligot, de Quatrefages, and Dumas, with the examination of the paper. On February 16 Dumas, who, for the purpose of obtaining the most trustworthy information on the subject, had repaired to Lyons, the centre of the French silk manufacture, laid before the Institute a comprehensive report, which, far from being exclusively devoted to the examination of M. André-Jean's experiments, minutely inquires into the general causes of the decline of sericulture both in France and elsewhere. The reader, to whom André-Jean's paper may have remained unknown, learns in the first place the remarkable results of his experiments and the way in which they were obtained, how the silkworms had to gain their food by climbing exercises, how the best climbers were selected for breeding, and how, by repeatedly submitting their offspring to a similar process of selection, strong races of silkworms were ultimately reproduced. The report gives a detailed account of these experiments, and proposes that they should be repeated on a large scale and for a long period in the south of France. On the other hand, it directs the attention of silk-growers to the necessity of carefully choosing the food of the worms. The leaves of young mulberry-trees and of such as are reared by grafting, or cultivated in wet soil, are found to exert a deleterious effect upon the worms, which become subject to a kind of atrophy, causing great ravages in the breeding establishments. Another cause to which the diseases of the silkworm are to be attributed is, according to the report, to be found in the fact of sericulture, which was formerly in the hands of rural populations, working on a small scale, having been gradually transformed into an industry performing its operations in colossal establishments. Lastly, from the experience gathered by the commission, it would appear desirable that the cultivation of silkworms should henceforth be separated into two distinct departments—the one having for its object the production of silk, the other exclusively devoted to the procreation of a strong race of silkworms for the purposes of breeding—since the conditions of success in these two branches of the industry are very different.

In a later report on the same subject the fine air of mountainous districts is pointed out as the most essential requisite for securing a healthy race of breeding worms.

But a much more serious danger than that arising from the deterioration of the breed of silkworms has of late been threatening the national wealth of France, by the appearance in her vineyards of the *Phylloxera vastatrix*. Everybody knows that viniculture is one of the most important industries of France, the produce of an ordinary vintage amounting to no less than 65 million hectolitres of wine, of an average value of 1,300 million francs. No wonder that any sufferings of the vinicultural districts should have given rise to a general feeling of alarm all over the country. Various papers on the subject were submitted to the Academy, which at once proceeded to the nomination of a Phylloxera Commission. On June 16, 1873, Dumas, in the name of this commission, which consisted of Milne Edwards, Duchartre, Blanchard, and himself, drew up a first report. This was more immediately elicited by papers presented to the Institute by MM. Duclaux, Max Cornu, and L. Faucon; but, faithful to his traditions, the author takes a survey of the whole question.

It was in 1865—we learn from his report—that in the vineyards of Roquemaure, in the Département du Gard, there appeared a new vinicidal parasite, then perfectly unknown to wine-growers as well as to naturalists, but which has since been recognised as one of the most formidable enemies of viniculture. Up to 1872 its devastations remained limited to the Département du Gard, but since then the insect has spread over other wine-producing departments, more especially over the Bordelais, threatening the vintage of the Gironde. After tracing the natural history of the Phylloxera as far as it is made out, the report gives a detailed account of the studies presented to the Academy. The observations of M. Duclaux, it goes on to say, are chiefly devoted to the geographical distribution of the insect over the wine-producing parts of France;

those of M. Cornu to the several stages of its metamorphoses. The latter has ascertained, moreover, that in the first stage of its development (in the beginning of April), it is particularly accessible to destructive agents, such as sulphuretted liquids, solutions of phenol, decoctions of tobacco and of *quassia amara*, &c., and he believes that appropriate applications of these substances afford a good chance of destroying the Phylloxera. M. Faucon, on the other hand, is of opinion that nothing short of actual submersion will save the vineyards. The report contains, moreover, an account of the chemical composition of the root of the vine, as established by Dumas's own experiments, and of the changes which, according to the observation of M. Cornu, this composition undergoes, when the root is attacked by the Phylloxera.

There are several later communications upon the same subject, and it should not be forgotten that among the different agents proposed for the destruction of the parasites, one of the most efficient—the alkaline trisulphocarbonates—was suggested by Dumas himself, who has, in fact, never lost sight of the subject, and is constantly keeping the Academy *au courant* of all inquiries relating to the Phylloxera question.

If, after what has been already said, proof were still needed of the invaluable services which Dumas's universality of attainments and ever ready eloquence have rendered to the Institute and to the French Academy, it might be found in the report he made in the course of last year on the so-called "Prizes for Virtue" (*Prix de Vertu*) conferred by the French Academy. These prizes were suggested anonymously to the Academy as far back as the year 1782, but were first instituted in 1820 by means of Montyon's handsome legacy, to which other bequests were shortly added. There is something singular in the original proposal, the author of which really seems to have aimed at a competition in the practice of virtue, just as prizes are nowadays offered for works of poetry, painting, or sculpture. This aim has, indeed, been long ago relinquished, and the prizes are now bestowed on unpretending acts of self-sacrifice, which are thus brought to light. It must, indeed, be no easy task for *Messieurs les Académiciens* to make the best selection, and a still harder one fitly to proclaim the names and merits of the chosen in an academical discourse. But this last problem is at present in safe hands, and Dumas, ever master of the occasion, knows how to solve it, by lifting the attention of his hearers up to the heights of philosophic contemplation, and letting them look down into the secret depths of the human heart. Who can withhold assent and sympathy from such words as these?—

"The truly loving spirit does good from a natural instinct. Therein lies its blessedness. It suffers more by the griefs of others than by its own, and in relieving a neighbour is itself relieved from an oppressive burden. It does not wait to be asked for help, nor does it seek for acknowledgment when the deed of mercy is done. It never finds itself prompt enough to assist the unfortunate, and its actions do not pass into oblivion with the speed it desires. It seeks neither witness nor reward; its modesty shuns renown."

We cannot but be deeply impressed by these beautiful words, words which we may also regard as the expression of the noble nature and lovable character of the speaker.

Dumas's commemoration speeches and academical reports, owing to the carefully-sifted information as to facts which they contain, will always be looked upon as documents of great importance. Of a more temporary interest are the numerous discourses which he has delivered on various festive occasions, although each of them is a little work of art in elegance of style, careful study, and appropriate treatment of the subject. In consequence of the extraordinary facility he possesses of accommodating himself to any task, he is everywhere in request. Thus we find him addressing large audiences on the occasion of the distribution of prizes at the Lycée Charlemagne, at the Lycée Louis-le-Grand, at the Polytechnic Association, at the Parisian School of Design, and last, not least, at the College of Alais, his native town. The discourse delivered there is particularly interesting, since it affords Dumas an opportunity of recalling the associations of his early youth. Among the numerous speeches of a similar kind, those made at the reopening of the Faculty of Lyons and at the inaugural meeting of the French Society for the Advancement of Science held at Clermont in 1876 may still be noticed.

Nor should the numerous non-academical reports be altogether left unmentioned. Not one of them but presents the question treated under a novel aspect. Dumas never touches a subject without raising it to the level of his intellectual powers. It would be difficult to quote a more appropriate illustration of this kind of report than the one drawn up on the occasion of the award of the Emperor's grand prize for electricity. In 1852 the Emperor Napoleon had instituted a prize of 50,000 francs to be awarded after five years by the Société d'Encouragement, for the most important discovery in the application of electricity to mechanical arts. The first competition, in 1857, had not elicited any invention worthy of the prize. The second, in 1864, was more successful, a number of serious competitors entering the lists. The commission appointed to award the prize numbered amongst its members the first physicists of France, but a chemist was, nevertheless, elected both president and reporter. The prize, it is well known, was awarded to Ruhmkorff for the splendid instrument bearing his name. In the report stating the motives of the award, Dumas gives a most interesting survey, not only of the services which Ruhmkorff's coil has rendered to science and industry, but also of the beneficial influence which the numerous and daily increasing applications of electricity in general, have already exerted, and are likely still further to exert upon the progress of the mechanical arts and manufactures.

If the limits of this sketch do not permit us to take more than a passing glance at this branch of Dumas's labours, we must be allowed to dwell somewhat more in detail upon a few literary achievements of another character.

It has been already stated that in 1824 Dumas founded, in conjunction with his friends Audouin and Ad. Brongniart, the *Annales des Sciences Naturelles*, in which some of his early researches, more especially those carried out along with Prévost, were published. It was but natural that his interest in this journal should considerably diminish when his attention began to be directed exclusively to chemical and physical questions. The natural channel for the publication of his papers was now the *Annales de Chimie et de Physique*, which at that period was the leading scientific journal of the world. Instituted in 1790 by de Morveau, Lavoisier, de Fourcroy, de Dieterich, Hassenfratz, and Adet, with whom Séguin Vauquelin and Pelletier were soon afterwards associated, the *Annales* ceased to appear under the Reign of Terror, but were resumed in 1797, and have since been published without interruption, a great many of the most distinguished men of science, among whom Monge, Berthollet, Chaptal, van Mons, Gay-Lussac, Thenard, D'Arcet, and Arago, may be quoted, being in succession connected with the journal. In 1840 Dumas became one of the editors, the Committee of Publication then consisting, in addition, of Chevreul, Gay-Lussac, Arago, Savary, Pelouze, Boussingault, and Regnault. Of this splendid array of *savants* only Chevreul, Dumas, and Boussingault are still alive, and it is under the auspices of these veterans, with whom Ad. Wurtz has lately become associated, that the *Annales de Chimie et de Physique* are now published. Dumas has thus been editor of the journal for nearly

forty years, but his contributions to it extend over more than half a century.

In the preceding pages we have dwelt at some length on Dumas's life-work, scientific and literary, for after all, in the portrait of a *savant* a view of his contributions to science will always be looked upon as the leading feature. But the achievements of a man of science and more especially those of an experimental inquirer, though in the first place invariably the fruits of his genius and perseverance, are always more or less shaped by the peculiar nature of his surroundings; and we must not therefore delay any longer to return to the events which in middle and later life have influenced the career of Dumas.

It will be remembered that we left the young chemist devoting himself to the duties of his newly-acquired professorship in the Royal Athenæum, and enjoying the use of the laboratory in the École Polytechnique, in which at last, by dint of perseverance, he had collected all the instruments and apparatus necessary for physical and chemical researches. A good many of the experimental investigations enumerated in a previous part of our sketch were performed in this laboratory.

The lectures at the Athenæum together with the literary engagements which they had occasioned, his duties as Répétiteur at the École Polytechnique, and the experimental researches continued without interruption would have left but little leisure to any man of ordinary energy. Dumas, however, found time for additional work. Well aware of the imperfection of scientific instruction for technical purposes in the then existing institutions of France, he conceived the idea of establishing, in conjunction with his friends, Théodore Olivier and Eugène Péclet, a school intended to supply the defect. The first step to realise this plan was taken on September 19, 1828, but failed in consequence of financial difficulties which presented themselves on the point of starting. The project, however, was soon resumed, with the assistance of M. Martin Lavallée, and the new school, which assumed the title of "École Centrale des Arts et Manufactures," actually opened in 1829. The extraordinary success of this institution and the important services it has rendered to French industry by the creation of a body of most competent civil engineers, are well known, and have found an able expounder in M. de Comberousse, whose lately published work gives the history of the institution from its origin to the present time. The school was founded without the assistance of Government, and has ever since continued independent, so that, when some years ago the necessity was discussed of liberating the institutions for the higher branches of scientific instruction from the trammels of official superintendence, Dumas was able to quote the École Centrale as a proof of the practicability of such a course.

"In France," he said, in addressing the Institute, "this freedom should have been granted long ago, and I may be permitted to point out an example which incontestably proves that it is neither opposed to our habits nor to the organisation of our budgets. The École des Arts et Manufactures originated, lives, and thrives without the co-operation of the State and without any connection whatever with other schools. It is owing to this independence, to this autonomy, which as one of its founders and as chairman of its council, I have always striven with my colleagues to preserve to it, that the École Centrale has taken and maintained its place among the most important and most efficient scientific institutions of the world."

At first Dumas lectured at the school on general, analytical, and industrial chemistry. At a later period, when its financial position permitted the appointment of additional chemical teachers, he confined himself to either one or other of these branches. The lectures on general chemistry he continued up to 1852, when he resigned in favour of Cahours. But although he no longer teaches, Dumas's interest in the institution is as active as ever. From its very foundation he presided over its council, an office, which, with a short interruption whilst Minister of Agriculture, he has held ever since and holds at the present moment. The École des Arts et Manufactures is a creation of which a man may well be proud, and we are not surprised therefore that the four founders should have united to establish a grand prize to be competed for by pupils of the school as a memorial of their glorious paternity. Towards the close of last year (September 19, 1878) Dumas had the rare good fortune to celebrate the jubilee of the institution he had founded, along with many who had received their education in it. On this occasion the staff of the school united for the purpose of presenting a work of art to the only surviving founder.

The number and variety of lectures which Dumas had to deliver at the École Centrale immediately after its opening, in addition to his duties at the Polytechnic School, rendered it an absolute necessity for him to diminish his engagements elsewhere, so as to enable him to find time for the various researches he had then in hand. Nor did he hesitate (in 1829) to retire from the professorship at the Royal Athenæum, to which Bussy was then appointed. The alleviation thus attained was not of long duration. In 1832 Gay-Lussac resigned his chair at the Sorbonne, which, like a natural inheritance, fell to Dumas; and to this position which he held up to 1868—when Henri Ste. Claire-Deville, after having acted as his substitute since 1853, became his successor—was soon added another important appointment. For when (in 1835) Thenard withdrew from his professorship at the École Polytechnique, the duties of this office devolved upon Dumas, who for twelve years had been a Répétiteur at the School. Dumas was, in fact, appointed, and remained in connection with the institution up to 1840, when he resigned in favour of Pelouze. The list of his professorial appointments, however, is not yet exhausted. After the death of Deyeux (in 1839) he was induced, chiefly by Orfila, to offer himself as a candidate for the chair of chemistry in the École de Médecine. This professorship had naturally some attraction for Dumas, who was just at that time deeply engaged in chemico-physiological researches. We have already had occasion to mention that it was in this position that he delivered his often quoted lecture on the chemical statics of organised beings, which gave rise to his controversy with Liebig. We thus find Dumas, in due course, connected with all the great teaching establishments of Paris save one. But though never permanently associated with the College of France, he was at all events in connection with that institution for a time. Indeed, it was there that he delivered his celebrated course of lectures on chemical philosophy, to which we have alluded in a previous part of this sketch, when temporarily taking the place of Thenard, who was then prevented, in consequence of ill health, from performing his professorial duties.

In these several positions Dumas had to lecture on very different subjects; he had moreover to shape his courses according to the traditions of the places in which he lectured, and to adjust them to the different ages acquirements, and wants of the students he addressed.

The opinion has been frequently expressed that lecturing on chemistry is a comparatively easy task. The chemical lecturer, it must be admitted, has some incontestable advantages. The elegance and variety of his experimental illustrations rivet the attention of his audience, while the countless applications of chemistry in the arts and manufactures and even in the transactions of every-day life, afford as many opportunities of interesting his hearers. But it cannot be denied on the other hand that facilities which constitute an undoubted element of success are not unfrequently also the source of failure, and that

by misusing them and heaping up facts before his pupils' eyes instead of setting forth the laws of their working, many chemical lecturers come to resemble those teachers whom Aristotle aptly compares to the shoemaker who supplies his apprentice with a number of finished shoes instead of teaching him how to make them. No doubt lecturing well on chemistry is as great an art as lecturing well on any other subject.

And that Dumas is a master in this art is unequivocally proved by the lively and lasting recollections which his lectures, addressed to such a diversity of audiences, have left in the minds of his hearers. Even those who have but had the good fortune of attending a single one of his lectures will ever remember the clearness and precision of his reasoning and the attractive grace of his delivery.

Dumas has always looked upon the phenomena of chemistry in the spirit of the naturalist yearning after classification, and in this respect the early lessons he received from his natural history patrons at Geneva had not been lost upon him. The happy talent for grouping and classifying unmistakably foreshadowed in his work on applied chemistry, and further developed and matured by long and painful studies is manifested in every one of his lectures. He never presents an isolated phenomenon or a notion not logically linked with others. The present arising from the past carries with it the presentiment of the future. The several chemical substances are always exhibited in juxtaposition with their analogues, so that the student becomes at once acquainted with the family instead of with a single individual, and is thus early led to the perception that the fundamental character belonging to the family appears with slightly shaded modification when the individual members of the family are contrasted, just as in the study of organic nature he finds a gradation of character in the species belonging to the same genus. It is, indeed, on comparative chemistry, if I may use the expression, that Dumas lectures.

These early efforts at classification, the value of which is but now fully appreciated, have left their stamp upon the present mode of teaching. Let us not forget that the order in which our manuals present the non-metallic elements and the groups in which we are in the habit of associating them, were introduced by Dumas, who more than a quarter of a century ago adopted the following arrangement :—

Group 1.—Hydrogen.
,, 2.—Fluorine, Chlorine, Bromine, Iodine.
,, 3.—Sulphur, Selenium (Appendix—Oxygen).
,, 4.—Phosphorus, Arsenic (Appendix—Nitrogen).
,, 5.—Boron, Silicium (Appendix—Carbon).

The modifications which the progress of chemistry has rendered necessary in this system are trifling. It is true we now speak of the oxygen, nitrogen, and carbon groups, though we cannot but admit that oxygen, nitrogen, and carbon greatly differ from the elements with which they are associated, and hold therefore a peculiar position in their respective groups. This peculiarity is clearly acknowledged by the above classification, which separates these elements from the other members of their groups by giving them in an appendix. The only essential change has occurred in the position of boron, which overwhelming experimental evidence has compelled us to transfer from the fifth to the fourth group. Again, the general expressions by which, in organic chemistry, Dumas represented his families—expressions which in our present notation have assumed the form of C_nH_{2n+2} for hydrocarbons, or $C_nH_{2n+2}O$ and $C_nH_{2n}O_2$ for alcohols and acids—have been ever with predilection retained by chemists.

And the scientific physiognomy of these lectures presented moreover an artistic feature. Each lesson had its carefully matured plan, its introduction, and its conclusion. Dumas made but few experiments, but they were well chosen and executed with faultless elegance. They formed, so to speak, part of the reasoning of the lecturer. Every thing foreign to his argument was carefully avoided; side paths, however seductive, would never induce him to leave the main road leading to his goal. There is no greater peril to the chemical professor than the overwhelming mass of details in the science. How often in chemical lectures is the student, from the sheer number of trees, in danger of losing sight of the forest. But Dumas never goes astray in the labyrinth of particulars; it is as if he had always before his mind those golden words of Schiller :—

"Was er weise verschweigt, zeigt mir den Meister des Styls."

These lectures had, however, another peculiarity, which the author of this sketch admired perhaps more than all the rest. This was the skill with which Dumas enlisted the sympathy and secured the mental co-operation of his students. From the very outset the height to be reached was seen looming in the distance, and when the difficulties in the way had been conquered and the point of survey attained the student left the lecture-room in a measure convinced that it was by his own efforts that the ascent had been accomplished.

Nor is it only in lectures that Dumas has sown broadcast the seeds of chemical science. He was in fact the first in France to adopt that efficient system of laboratory teaching so happily inaugurated by Liebig, which has ever since been a prominent feature of the German universities. The laboratory which he had established in the École Polytechnique, though well adapted for an experimental inquirer working along with his assistant, was altogether unfit for the reception of a number of pupils. That he might be able to associate with experimental students, he founded as early as 1832 a laboratory of research at his own expense. Originally located at the Polytechnic School this laboratory was in 1839 transferred to the Rue Cuvier, where it remained till 1848. It was in this laboratory of research that he worked with his friends and scholars, it was there that men like Piria, Stas, Melsens, Leblanc, Lalande, Lewy gathered around him, and that some of those standard investigations were carried out to which in a previous part of this sketch we have already had occasion to allude.

When the revolution of February broke out, Dumas, in consequence of his income being considerably diminished, was no longer able to keep up a laboratory entailing a heavy annual expenditure, as he would receive none but a few advanced students, and these on terms absolutely gratuitous. For a time he was compelled to give up his experimental teaching. Under the Empire his laboratory was transferred to the Sorbonne, where, three or four years later he instituted his researches on the atomic weights of simple bodies; in 1868 it was removed to the École Centrale.

The close of Dumas's laboratory of research in 1848 was generally looked upon as a scientific calamity. An anecdote—which the author of this sketch heard from Dumas himself—gives proof of the regret it caused in wide-spread circles. During the troublous times which followed the revolution of February, Dumas received one day a visit from a person whose family was afterwards to attain a certain celebrity. His strange aspect and blunt demeanour were by no means prepossessing. "They assert that you have shut up your laboratory," he said, "but you have no right to do so; if you are in need of money—there"—and he threw on the table a roll of bank-notes—"take what you want, do not stint yourself; I am rich, a bachelor, and have but a short time to live." "But I do not know you, sir." "No matter, my name is Jecker; I am a pupil of the Medical School of Paris, and consequently of yours. I am passionately devoted to organic chemistry; I have made my fortune by what I have learnt in Paris, and I am now paying a debt." This conversa-

tion resulted in nothing more than mutual good-will. Dumas could not accept Dr. Jecker's liberal proposal, as his mind was not then free for experimental researches. But he was soon to learn that the excellent man who so unexpectedly came to offer him his assistance had in no respect deceived him.

Dr. Jecker succumbed in 1850 to the disease whose existence he had referred to, and, agreeably to the advice of Dumas, left 200,000 francs to the Academy of Sciences for the foundation of an annual prize intended to promote the progress of organic chemistry. The Academy instituted the *Prix Jecker*, and it is well known how many cultivators of chemistry have since been benefitted by Dr. Jecker's noble bequest. Alas! the beneficence of the uncle could not preserve his unfortunate nephew from the furies of the Commune in 1870.[1]

Almost immediately after the revolution of February new labours of the most diverse kind begin to encroach upon Dumas's scientific work. The political and social upheaval of 1848, shaking, as it did, the stability of all French institutions, turned into political and administrative courses many men of mark whose energies had been hitherto exclusively devoted to the service of science. It would have been strange, indeed, had not the want been felt of securing Dumas's well-tried powers for the public affairs of the country. And, on the other hand, can a richly-gifted scholar, whose co-operation in the restitution of affairs had been loudly claimed by public opinion—can such a man reject the proffered trust that he may continue to give up his whole time to the cultivation of science? How easy or how difficult it was for Dumas to answer this question we cannot tell; but we know that when once his decision was made, it was no half-hearted aid he lent. Election to the National Legislative Assembly, appointment as Minister of Agriculture and Commerce, admission to the Senate, Presidency of the Municipal Council of Paris, and nomination as Master of the Mint of France, are the steps by which he speedily rose in his new career. That the time and energy devoted to these important positions were lost to scientific investigation, none, least of all Dumas himself, can doubt. The constant succession of experimental inquiries which it had hitherto strained the minds of chemists to follow now begin to appear at longer intervals, but always frequently enough to show that their author, despite the load of work that from so many quarters demands his attention, never loses sight of the development of science. Often, too, we think we can read between the lines how painful to him is this renunciation of the unbroken pursuit of scientific inquiry. Indeed, on more than one occasion has Dumas clearly expressed this feeling. In a letter addressed but a few years ago to one of his friends, he touches upon this very subject. "My life," he says, "has been divided between the service of science and that of my country. I would rather have remained the servant of science alone, but, sprung from the obscure ranks of the democracy, I always thought that my country had done so much for me that no devotion on my part could be refused to it. If I have deceived myself, science itself will not hold me guilty. In limiting myself to scientific pursuits, I should have been happier, my life would have been a less anxious one, and perhaps I should have attained a larger view of truth."

At the same time Dumas has not been altogether spared the reproach to which he refers. How much more rapidly, some have exclaimed, would chemical science have advanced had this creative force been expended in her service alone! It sounds strange, indeed, that he who has given much should be blamed for not having given more. Such a reproach, moreover, can only be made by those who are ignorant of what has been accomplished in parliamentary and administrative labours by the object of their censure. Dumas's political activity is certainly no noisy one. He scarce busies himself with those questions of high politics which so excite the public mind, and he seldom appears on the orator's platform; but just on this account is his influence more powerful. Whenever the question is one of social science the penetration of which involves comprehensive chemical and physical knowledge and devoted study, it is Dumas who is intrusted by his colleagues with the problem, and who, with ready self-sacrifice, devotes his powers to its solution. And when he does ascend the tribune, it is no demagogue's lecture we hear, but a well-thought-out essay in political economy, equally remarkable for the exhaustive scientific treatment of the subject and for the seductive elegance of its form, the interest in which does not die with the ephemeral circumstances of its origin.

Dumas's Parliamentary career opened almost immediately after the revolution of February, when the electors of the arrondissement of Valenciennes—which is largely engaged in the production of beet-root sugar—believing that they would find in him a representative competent to defend their interests, chose him for their deputy in the Legislative Assembly. Shortly afterwards the President of the Republic called him to fill the office of Minister of Agriculture and Commerce, and Louis Napoleon conveyed the invitation in the flattering words: "You will be my Chaptal," alluding to the fact of the celebrated chemist having held this office under the First Napoleon. Among the bills brought by the new Minister before the Legislative Assembly, those of a State credit to working-men's Associations (1849), of banks of mutual assistance for the working classes (1849), of land credit institutes (1850), and of a retiring fund for the aged may be mentioned, nor should the share he had in the introduction of local competitions in agriculture, in the creation of the Agricultural Institute, in the establishment of public baths and lavatories, in the suppression of the lazaretto of Marseilles, and in a new organisation of quarantine, be left unnoticed. Among the institutions which Dumas's tenure of office has left to the country the Land Credit Institute (*Credit Foncier*) and the Government Retiring Fund for the Aged (*Caisse des Retraites pour la Vieillesse*) are the most important. Of these the former rivals the Bank of France, while the latter not only affords great assistance to aged workmen, but also constitutes a very powerful means of redeeming the public debt, since every annuity becomes extinct at the death of the holder.

During the second Empire, Dumas was elevated to the rank of Senator, which, indeed, he held up to September 4, 1870. The author of this sketch refrains from attempting to give a full account of the services which in this capacity he rendered to his country. Not being sufficiently acquainted with the several subjects involved, he would scarcely be able to enter into the details necessary for their appreciation; all he can do therefore is to show the diversity of interests Dumas promoted, by enumerating the prominent subjects which, either in the form of reports drawn up in the name of commissions (he never formed part of a commission without being elected reporter) or of special discourses, he has brought under the consideration of the Senate. Thus we find him addressing his colleagues on the project of re-casting the copper coinage (1852), on a law of drainage (1854)—perhaps the most lucid exposition ever given, not only of the science of drainage, but also of the vast experience gathered in England on this subject—on the preservation of the mineral springs of France (1856), on trade-marks (1857), on petitions regarding the treaty of commerce between France and England (1860), on the organisation

[1] Dr. Jecker's brother was a banker of note in Mexico, whose financial affairs—so the story goes—were involved in the Mexican Expedition. His son, the nephew of the doctor, had come to Paris in order to establish some claims he thought he had on the French Government. He was surprised by the Commune, and the circumstance of his name having been mixed up with the Empire proved fatal to him. He was arrested, imprisoned as a hostage, and became a victim of the last convulsions of the Commune, being shot along with the Archbishop of Paris in the court of the prison of La Roquette.

of medicine (1860), on the government fund for the aged (1864), on petitions regarding the age of admission to the examination for the degree of bachelor (1864), and, last not least, on homœopathy, a discourse lashing with inimitable humour the doctrine of *similia similibus*, and received with stormy hilarity by the Senate.

Having been called shortly after his entrance into the Senate to the Vice-presidency of the High Council of Education, Dumas had to resign his teaching functions, not being able to expose himself to the disturbances which political passions can excite even in the scientific lecture-room. But in MM. Wurtz and Henri Ste. Claire-Deville, both illustrious representatives of chemical science, he found able substitutes to fill his places at the School of Medicine and at the Sorbonne.

He had arrived at that time of life in which he could promise himself the leisure necessary for protracted researches, when his presence was required in the Municipal Council of Paris, in order to bring to a close the grievious state of neglect in which the city had then left the Sorbonne and the Lycées—institutions of which the University had the use, though they belonged to the town, which ought, therefore, to have kept them in good condition. With this definite object he entered the Municipal Council, and was soon elevated to the vice-presidency (1855), and then to the presidency of the same (1859)—an office in which, under the reign of Louis Philippe, he was preceded by no less a man than Arago. At the head of the Municipal Council of Paris, over which he presided up to September 4, 1870, it fell to Dumas to take an active part in the endless variety of labours which, during a most memorable period, this influential body had to perform. It is true the Municipal Council of Paris is only a deliberative board, the executive being in the hands of the Prefect of the Seine. No one, however, who even from a distance has witnessed the marvellous metamorphosis of Paris which signalised the second Empire, is likely to look upon the municipal presidency as a sinecure. But any one who would obtain an adequate idea of the responsibility of this office, of the extent and multiplicity of its duties, and of the sacrifice of time and labour the performance of them involves, should read the allocution on the work done by his administration addressed by Dumas on October 28, 1859, to the Prefect of the Seine, when, on the occasion of the suburban districts comprised within the fortifications being incorporated in the municipality of Paris, the Council was dissolved.

In carrying out the astonishing changes which this epoch had inaugurated for Paris, the Municipal Council naturally felt the necessity of providing the metropolis on the Seine with a system of arteries and veins by which the daily increasing population might be supplied with fresh and pure water, and fecal matter and other filth be removed with certainty and expedition. A remarkable plan for the solution of this most important question of public health had been elaborated by the Prefect of the Seine. In the beginning of the year 1859, this plan, together with other proposals having the same object in view was brought before the Municipality of Paris, which thereupon appointed a special water-commission, and as early as March 18, Dumas, in the name of this Commission, made a comprehensive report to the Municipal Council, in the first place on the water-question. Dumas's report is so interesting that we cannot resist the temptation of reproducing some of its leading features.

The problem was to furnish the town with a quantity of pure and fresh water of constant temperature, sufficient to supply a population of 2,000,000 at the rate of 200 litres daily per head, and to have the water delivered even in the topmost stories of the houses situated in the highest quarters of the town. For the solution of this problem three chief plans were submitted.

Whoever knows Paris must remember the beautiful fall of the Seine near the Pont Neuf, opposite the Quai de la Monnaie. Mary, Inspector-General of Public Roads, had already conceived the idea of turning it to account, by using the fall as a motive power for raising to the necessary height the water to be distributed over the town. Girard, the celebrated hydraulic engineer, following out this idea advised the Commission to erect a system of turbines of his construction so as to utilise this fall. On the other hand there was an elaborate project of Lechâtelier, the engineer, who proposed to raise the water by ten steam-engines of 100-horse power each. Both plans contemplated using the water of the Seine, which was to be drawn from a higher part of the river and to be filtered before distribution. Opposed to these two projects was that of the Prefect of the Seine, a magnificent conception of Belgrand the engineer, who, rejecting all artificial contrivances, relied upon the natural fall of the water to be brought into the town. He had in view nothing less than to collect in the valleys of the Somme and Soude, and those of the Dhuis, Berle, and Sourdon, the atmospheric water which, like a subterranean lake, is stored up in the chalk of the Champagne, resting upon impermeable clay, to conduct it to Paris and to raise it for storage in reservoirs 80 metres high for distribution in the town. To this end the water had to be brought a distance of 253 kilometres, passing no less than seventeen bridges, while 6 kilometres had to be traversed on viaducts, 7 kilometres in pipes, and 28 kilometres in tunnels. The preliminaries, carried on for several years, for drawing up this plan, correspond to the magnificence of the project. The hydraulic properties of the soil, extending over 75,000 square kilometres of country, were investigated in the most careful manner; not less than 194 springs as well as all neighbouring rivers and streams, were gauged and analysed; lastly, the daily variations in volume and clearness of the rivers and streams were for years observed at twenty-five well-selected stations. The cost of the whole undertaking was estimated at 30 million francs.

Dumas's report examines all these schemes and especially the numerous questions suggested by Belgrand's project, with a knowledge of details obtainable only by the study of years; thus bearing a beautiful testimony to the carefulness and conscientiousness of the author.

The report gave rise to a most animated discussion in the Municipal Council. All the members of Council who were natives of Paris looked upon the water of the Seine as the best and purest in the world, so that, in order to carry the proposal, proof positive was needed of the polluted state of the water which the machines of Chaillot supplied to the inhabitants. But when Dumas showed that with every forty-two cubic metres of the water of the Seine a cubic metre of sewage passed the Pont Royal, and that this odious mixture was raised by the Chaillot-machines and distributed to the citizens, even the fanatical admirers of the nymph of the Seine began to suspect her virginity. And their suspicions were fully confirmed when specimens of the water of the Seine and of that of the Dhuis having been kept in bottles for some weeks, the latter remained clear, inodorous, and drinkable, while the former was disturbed, slimy, tainted, and repulsive—so that no one could be induced to drink it. Convinced thus by a chemistry within the range of their comprehension the Council were induced to vote the funds necessary for bringing in the spring water of the Dhuis. And thus it was in a great measure through Dumas's powerful exertions, maintained against the most determined opposition, that the scheme of introducing spring water by aqueducts and tunnels triumphed over the rival plan of providing the town with the water of the Seine raised by machinery, and that the city of Paris boasts of a water supply which may enter the lists with the gigantic works of Roman antiquity.

Nor should it be left unnoticed that the last visit of the

cholera to Paris, occurring after the higher quarters on the right bank of the river were already supplied from the Dhuis, proved the advantages which might be anticipated for public health from the use of this water. These quarters, usually most severely attacked by epidemics, were now amongst the least affected—if indeed not entirely spared.

While the grand works for the Parisian water supply were in progress, the Municipal Council of the city did not lose sight of other resources which presented themselves. It is well known that under the auspices of Arago, Dumas's predecessor at the Hôtel de Ville, a splendid success had been achieved by Mulot in the sinking of the artesian well of Grenelle. The idea naturally presented itself of augmenting the supply of water thus obtainable by opening similar wells in other districts of Paris. As far back as 1853 the hydraulic engineer Kind had proposed to sink a second well with a bore-hole 60 centimetres in diameter instead of 30, the diameter of the bore-hole of Grenelle. The work was commenced on December 23, 1854, at Passy, at a distance of 3,500 metres from the well of Grenelle, and in March, 1857, a depth of 520 metres had been reached without any accident worth mentioning. But now a succession of obstacles presented themselves by which at one time the whole undertaking appeared to be called in question, and which indeed could only be overcome by enormous sacrifices. Still the courage of the commissioners did not flag, and on September 31, 1861, Dumas had the satisfaction of announcing to the Academy of Sciences the brilliant success of this grand experiment, for which the City of Paris had paid upwards of a million of francs. On September 21, at noon, the water sprang in such abundance that 15,000 cubic metres were delivered within the first twenty-four hours. This quantity subsequently rose to 25,000 and ultimately subsided to an average of from 21,000 to 22,000 cubic metres. Dumas's report gives a number of most interesting details, more especially as to the effect which the opening of the new well had upon that of Grenelle. The yield of the latter sank in consequence from 900 to 777 cubic metres, at which rate the flow became constant again after thirty hours; so that more than a day was necessary to establish the equilibrium of the water in the two wells, situate at a distance of 3,500 metres from each other.

Closely connected with the question of the supply of water to towns is that of their speedy and effectual drainage. The latter, indeed, is a corollary of the former. The most opposite views on the subject were advocated in the Municipal Council under Dumas's administration. The disposal of the sewage of an immense city like Paris presents a series of difficulties the gravity of which can be appreciated only by those who have had actually to grapple with the subject. Dumas has never published an elaborate report on the drainage of Paris comparable to the document on the supply of water, but he has frequently and unmistakably expressed the opinion he held on this matter. Of course, engineers did not hesitate; drains were to be constructed to receive the sewage and a flush of water was to be supplied sufficient to carry it into the Seine which, as the main sewer of the town, would convey the sewage so diluted to a distance, and ultimately to the sea. This system, applied to towns on the banks of a rapid stream, might be capable of defence; but with a gently-flowing river, whose sinuous course keeps the water long in the proximity of the town, it was but to defile the bed of the stream with the seeds of infection, which at no distant date would render the city uninhabitable. Dumas would never accept such a proposal, and asserted with unwearied perseverance the necessity of preserving and utilising the sewage for agricultural purposes, converting the solid excrement into manure by desiccating it in closed vessels, and employing the liquid sewage as an agent of irrigation.

The lighting of Paris and its suburbs was at that time in the hands of different companies, which supplied gas of diverse price and quality. The chief company had agreed to absurd conditions as to the lighting power of the gas it bound itself to furnish, and consequently was fined about 1,000 francs a day for want of lighting-power. All these difficulties were brought to a close by a long series of researches carried out in Dumas's laboratory. The adoption of a new burner increased, without expense, the quantity of light supplied to the streets. New and economic combinations, moreover, permitted the reduction by 25 per cent. of the price of gas for individuals as well as for the town, and, at the same time, secured for the municipal purse a share in the profits, which amounted to eight or ten millions a year. Many other towns have followed the example of Paris in making arrangements with their local gas companies, and having adopted the system of verifying the lighting power and purity of gas introduced by Dumas and Regnault, the collisions between municipal interests and private enterprise, hitherto so frequent, have entirely disappeared.

On this subject Dumas tells us that by enlarging the slit of each gas-burner and diminishing the height of the lamp, the quantity of light thrown on the pavement is nearly trebled. And here an anecdote, which the author of this sketch has from the best of sources, may find its place. Dumas was anxious to see what effect this change would have on the inhabitants if suddenly carried into effect in an important and central part of Paris. The gas-burners were changed in one day, so that in two successive nights the old and the new systems of lighting might be compared with one another. Dumas waited till dark, and then paced the streets, so that he might enjoy the fruits of his protracted labour, but no one noticed that any change had taken place. The next day, at a favourable hour, he proposed to his friend Balard that they should take a walk together, and during the walk he said to him from time to time, "Do not you find that the gas seems brighter than usual?" But Balard saw nothing, and went on with the previous conversation. Some days afterwards the shop-keepers of the rue St. Honoré, more observant than the public and than Balard, came, not to express their thanks for the improved lighting of the streets—far from that—but to complain that the companies furnished the town with better gas than they did private houses. Without having reduced the amount of gas they burned, they found that whereas formerly their windows shone at the expense of the street, it was the street that eclipsed them now. Such is the reward to be reckoned on by those in charge of municipal affairs—indifference, if not ingratitude.

We have still to allude to a last phase in Dumas's official life. In 1867 chemical science in France suffered a severe loss by the lamented death of Pelouze, whose name we have already had occasion to mention when speaking of Dumas's commemorative addresses. Pelouze had been Master of the Mint, or, to quote his official title, "President de la Commission des Monnaies," and after his death very powerful efforts were made in certain quarters to snatch from scientific circles an office traditionally regarded, so to speak, as an endowment of science. These exertions, however, happily failed, when, at the eleventh hour, Dumas presented himself as a candidate for the appointment. It would have been difficult not to acknowledge claims so legitimate. As far back as the reign of Louis Philippe Dumas had been habitually consulted on monetary matters; at the request of the Minister of Finance he had often inspected the provincial mints of France, and on more than one occasion had he been charged, as Royal Commissioner, with the defence of the different legislative proposals on monetary affairs which the Government brought before the Chambers. In 1839

the Minister had entrusted him with the important and delicate mission of studying the processes and apparatus of the Mint of England. He had drawn up, moreover, a comprehensive report embodying the results of his investigations as to the composition, actual weight, and expense of the French currency—a report which, though printed only in a dozen copies for the use of a superior commission, has been the basis of many decisions of State, and of a number of subsequent publications of the commissioners. Some other papers on coinage might be quoted, amongst them a note on the copper coinage in circulation and its utilisation in the manufacture of bronze coins, read before the Institute on July 13, 1846, and two reports addressed to the Senate, on the re-coinage of the copper currency (May 2, 1852), and on a new silver coinage (May 12, 1864).

In the beginning of 1868 Dumas was appointed Master of the Mint of France; but strange enough, as if foreboding his ephemeral tenure of this office, he never moved into the gorgeous residence belonging to the appointment, preferring the comfort and tranquillity of his modest dwelling in the rue St. Dominique to the splendours of the princely mansion on the Quai de Conti.

With the fall of the second empire the political and administrative career of Dumas came to an abrupt termination. The Senate had ceased to exist, and in the stormy days which followed, the Municipal Council had naturally changed its composition, and even in the Mint, where his rich experience and his rare talent of organisation might have been still of such use in the public service, the man who played so conspicuous a part under the Imperial Government had to vacate his place. Since his withdrawal, the management of the French Mint has passed into the hands of an administrative officer. Strange that both in France and England the Mint should have been lost to science! The number of great social positions which the State has to bestow on prominent scientific merits, is, more especially in England, so very limited, that this loss is much to be deplored. What a fine opportunity for an English Minister, of promoting, though indirectly, the interests of science! Let him restore to it an office, which at one time was held by the immortal Newton, and which more recently men like Sir John Herschel and Thomas Graham have adorned!

Having thus withdrawn from his official positions, Dumas found himself at the age of seventy in the possession of *otium cum dignitate;* but he never allowed himself to enjoy it in any other than the Ciceronian acceptation of the words. Since his retirement from political and municipal life Dumas once more exclusively belongs to science. There is no chemical aspiration which he is not anxious to assist, no problem in the domain of chemistry, physics, or physiology to the solution of which he is not happy and proud to contribute, no scientific movement of any kind to the furtherance of which he is not willing to open the treasury of his matured experience or to lend at least the prestige of his name. But he is never more happy than when, in furthering science, he is at the same time able to serve the material wants and to promote the well-being of his fellow-citizens. And occasions for enjoying this happiness are not wanting.

Among the numerous enterprises of public interest in which of late Dumas has prominently co-operated, there are two upon which, owing to their universal importance, we have still for a moment to dwell. We allude to the international permanent commission on the metre, and to the transit of Venus expedition.

It is well known that in 1869, the French Government, complying with the request of the Academy of Sciences, and the wishes of learned corporations and societies of other countries, had invited the different states of Europe and America to send delegates to Paris for the purpose of forming an international commission, under the auspices of which a standard metre (a *mètre à traits*), intended to serve as an international prototype, should be constructed. This international commission (*Commission Internationale du Mètre*) met for the first time in August, 1870, and again, after peace had been concluded in September, 1872. The result of their deliberation was the proposal of a permanently organised international supervision of weights and measures, viz., the foundation of an International Board of Weights and Measures in Paris, the creation of an International Committee with the Board just mentioned for its executive, and lastly, the agreement to intrust the construction of the typical metre to the French section of the *Commission du Mètre*. They at the same time, before adjourning appointed a committee for the superintendence of the important labours of the French section, and for generally carrying out their resolutions. In October, 1873, and again in the same month, 1874, this committee had requested the French Government to take steps for the convocation to Paris of an international diplomatic conference, charged with the duty of examining into the best mode of establishing the Board proposed. This diplomatic conference actually met on March 1, 1878, under the presidency of the Duc Decazes, then Minister of Foreign Affairs, and their first resolution was to appoint a special commission, consisting of its scientific and technical members, whom they intrusted with the framing of the detailed project for discussion.

It was at this stage that Dumas, who had not hitherto formed part of the Commission, became connected with their proceedings, over which he at once gained a preponderating influence. He had been appointed a scientific delegate to the diplomatic conference, which, in turn, entrusted him with the presidency of the special commission just mentioned. Guided by his consummate business tact so often tested, this commission rapidly accomplished its task, and as early as April 12 Dumas was enabled to lay the result of their labours before the conference. In a masterly speech, of which a full record is preserved in the minutes of the conference, he sketched in clear outlines the movement which had given rise to their proceedings; he showed how, ever since the first International Exhibition of 1851 in London, nations had become more and more convinced of the necessity of an international system of weights and measures, how, under the pressure of this conviction within the comparatively short time of twenty years the metric system had been almost universally adopted; how in consequence of this general adoption an increased interest was felt in the preservation of standard types of the metre and of the weights derived therefrom; and how it was now proposed to place their safe keeping in the hands of an international board, to be permanently established in Paris. Dumas's eloquent address—such is the opinion freely expressed by members of the conference—won the day. When the conference had first met the opinions of the delegates were greatly divided, so much so, indeed, that at one time the whole project appeared to be in danger. Dumas succeeded in gaining the unqualified adhesions of fourteen States out of twenty represented at the conference; five adhered but wished to refer the question once more to their respective governments, and only one State (Holland), whilst admitting the necessity of ample provisions for the safe keeping of the standards, objected to the appointment of a permanent international board.

Everybody knows that for several years the international board of weights and measures has been in active operation, but few are aware of the powerful influence Dumas has exercised upon its realisation.

Dumas, indeed, appears to be predestined to presidency, for we find him also at the head of the commission superintending the preparation of the French transit of Venus

expedition. How came it that a task essentially astronomic was intrusted to a chemist? When in 1872 and 1873 the Academy discussed the steps to be taken for enabling the French astronomers to participate in the observations of the transit of 1874, a strange circumstance occurred in the withdrawal from the enterprise of Le Verrier, to whom, from his scientific position, the privilege of taking the lead in this affair appeared to belong. The celebrated astronomer expressed his reluctance to incur the large expenditure of force and money necessarily involved in starting these astronomical expeditions, since their main object, the determination of the ratio of the dimensions of the earth to those of the planetary system, would in his opinion be before long more simply and surely ascertained by observing the disturbing influence which the earth's mass exercises upon the movement of its planetary neighbours. This feeling of disfavour arising from Le Verrier's scientific convictions, was, however, by no means shared by the other French astronomers, who, together with geographers and hydrographers, attached considerable importance to the expedition. Nor could chemists and physicists refuse their interest to the observation of phenomena, by which the photography of precision was likely to be greatly benefited. Under these circumstances it was welcomed as a most fortunate solution of the difficulty, that Dumas, remembering perhaps his early association with Laplace, did not shrink from placing himself at the head of the movement, which was now unhesitatingly joined by several of the most prominent astronomers and physicists of France. And thus the French transit of Venus expedition was successfully carried out under the auspices of Dumas, who on October 9, 1876, was able to announce to the Academy of Sciences the publication of the first volume of their observations.

Opportunities of indulging in the noble passion of promoting the advancement of science are ever afforded to Dumas in his association with the Institute and the Society for the Encouragement of Natural Industry. Elected a Member of the Academy of Sciences in succession to Sérullas, as far back as 1832, he had succeeded Flourens as Permanent Secretary in 1868. As regards the Société d'Encouragement, he is the third chairman of this association, which was founded early in this century (1802), having been preceded by Chaptal and Thenard, the latter of whom resigned the chair in 1845. The office of president expires with the year, but the present chairman has for thirty-four years been re-elected. Ever most conscientious in the fulfilment of duties undertaken, Dumas, now that he is released from the trammels of official life, is devoting himself, if possible with increased energy, to their performance. But it is more especially in his capacity of Permanent Secretary of the Institute that he displays that ardent love of scientific discovery, that continued interest in the progress of thought, which is the delight of his friends and the admiration of his contemporaries. An ever-ready interpreter of the researches of others, he always heightens the value of what he communicates by adding from the rich stores of his own experience, thus often conveying lights not noticed even by the authors of those researches. It is this lively interest in the work of others, this thorough entering into the pursuits and deep sympathy with the aspirations of the younger generation of chemists, which constitute the secret by which Dumas has preserved the youthful spirit untouched by the feeling of isolation which so often saddens the evening of life, when, one by one, our companions-in-arms, our fellow-workers, those with whom we trod the sunny paths of youth, are disappearing from the stage.

It has been often observed to be a peculiar feature of the later years of life that the speculative element recedes, whilst inquiries of a practical tendency, and more especially such as refer to the well-being of man, claim attention more prominently. This observation applies also to Dumas; it is more particularly on topics of applied chemistry that he now addresses the Academy. Starting generally from notices submitted to the Institute, he will discourse on the disinfection of the sewage of large towns, on the purification of the air of hospital wards, on the poisonous character of mercury vapour, on the contamination of water by lead, or, resuming subjects of earlier inquiries, on the diseases of the silkworm, on the devastations of the phylloxera, and the processes suggested for its extermination; or he will dwell upon the investigation of alimentary substances stating his opinion as to the nutritive value of cocoa, as to the relative values of ground and unground corn, or on the meat supply of Paris, or, lastly, he will take his subjects from chemical technology, and speak on nickel-plating, on the effect of great cold upon metals, or on similar subjects. But topics of purely scientific interest are by no means wanting. The interesting researches on the fermentation of alcohol (1872) and the recent very important paper on the occlusion of oxygen in silver (1878), to which we have already alluded, belong to this period. Again, the important communications of Pictet and Cailletet, on the liquefaction of gases, or Norman Lockyer's startling spectroscopic observations, could not fail to revive the speculative predilections of his younger days.

It need scarcely be added that on all festive occasions involving an eloquent manifestation, Dumas is invariably the spokesman of the Institute. When in 1872 the members of the Institute resolve to commemorate the eighty-sixth birthday of Chevreul by presenting a medal to the venerable Nestor of chemistry, who but his illustrious chemical colleague should be chosen to deliver the address, than whom no other member had been so long an eye-witness of Chevreul's glorious services to science? Again, when in 1874 a message flashes across the Atlantic in which the Emperor Dom Pedro II. announces to his colleagues on the banks of the Seine that France and Brazil are henceforth physically united, who but the great chemical philosopher of the Academy should be intrusted with the reply to the Imperial Correspondent?

Indeed the intervals between the occasions on which he addresses the meetings of the Institute or of the Société d'Encouragement, are neither long nor frequent, and thus it happens that those, who, separated by considerable distances, have no longer, as they had in early life, the good fortune of frequently associating with Dumas, are now delighted, week by week, when opening the *Comptes Rendus* or the *Bulletin* of the Society, to receive the welcome tidings of his continued health and uninterrupted activity.

That to scientific services continued for upwards of half a century science should have accorded with unstinted hand a rich share even of her external marks of honour was but to be expected; no academy, no learned society, but has deemed it an honour to inscribe the name of Dumas on its register! A Member of the French Institute at the early age of thirty-two, he has in due time reaped the full harvest of distinctions in store for successful cultivators of science. He became a Correspondent of the Berlin Academy of Sciences in 1834 and a Foreign Associate of the Royal Society in 1840. He is an Honorary Member of the English, French, and German Chemical Societies. These associations, the second of which originated in Dumas's laboratory, elected him as a matter of course immediately after their institution. In 1843 the Royal Society awarded to him the much-coveted Copley Medal. That he was the first to obtain the Faraday Medal, in the gift of the Chemical Society of London, has been already mentioned. Dumas is a Knight of the Prussian order *pour le mérite*, the highest scientific honour Germany can bestow, and it may further be added that he has received the Grand Cross of the Legion of

Honour and is a knight of a goodly number of orders in Christendom.

In approaching the conclusion of this biographical notice of our great contemporary, the author naturally feels some embarrassment. He has given the birth and parentage of his hero, he has carefully chronicled the prominent events of his life, he has delighted in enlarging on his achievements, and endeavoured to trace them in correlation with the time and circumstances in which they were accomplished; but he is painfully conscious that there is still a blank in the portrait. He has not yet spoken of the character of the man, of the kindness and geniality which endear him to his friends, of the never-failing readiness to advise and to help which has gained him the affection of his colleagues, and of the integrity of his life, which has secured to him the esteem of his fellow-citizens. But he has purposely refrained from more than alluding to these noble qualities, lest his portrait might assume the colouring of flattery, painful alike to the subject of this sketch and to its author. Dumas's future biographer—may the time be distant when he puts pen to paper—will furnish the picture sketched here in slender outlines. Some of these qualities, however, are so characteristic of the man that it would be an ill-advised self-denial were we, from mere fear of misconception, to neglect referring to them, more especially since it will only be necessary to quote his own words in illustration.

Dumas is a Frenchman in the fullest sense of the word. Nothing is dearer to him than the country of his birth, to which he is passionately attached. His numerous orations and addresses of every kind give him ample opportunity—much more so than usually falls to the lot of a scholar—of expressing this feeling. On such occasions his language takes the warm colouring of his southern home, as he repels attacks on the honour of France in words of passionate vehemence, or celebrates her glory in almost dithyrambic strains.

To those who, from a superficial acquaintance with France and Frenchmen, think themselves justified in pronouncing scornful judgments upon them, how impressive must the apology sound by which, in his oration on Guizot, he defends the much-abused country!

"When, in self-calumniation, France exposes on the stage or in novels the vices of her great cities, and would make believe that her civilisation is on the wane, do not hearken to her! She forgets the sober virtues practised noiselessly in the country, where the peasant tilling the ground, sowing the seed, and reaping the harvest, reinvigorates by the labour of actual life the forces weakened elsewhere by the allurements of a factitious existence. No! we shall not be degraded by those lower and sensuous propensities which characterise nations in their decline, and our children, the hope of an afflicted country whose eagerness to work doubles with her misfortunes, shall never repudiate that glorious heritage of intelligence and ideas—a heritage still intact—which our fathers have bequeathed to us."

It is always a true and manly patriotism that inspires Dumas's words. He is never happier than when celebrating the grand exploits of his country, or when extolling the advances which science owes to the efforts of French scholars, and chemistry in particular, to the immortal labours of Lavoisier. But it is no one-sided praise that he distributes. He neither forgets nor depreciates the scientific merits of other lands.

It cannot, of course, be expected that Dumas's enthusiastic admiration of his country will be as well appreciated by Englishmen and Germans as it is likely to be by Frenchmen. In England as well as in Germany many are inclined to believe that the first article in the creed of Frenchmen is the conviction of their superiority to their neighbours. There is no doubt a grain of truth in this opinion, and it would not be difficult to find in Dumas's writings, passages which might be interpreted in the light of such an idea. Indeed, listen to the panegyric by which, in the commemoration address on Guizot, just quoted, he extols his beloved France:—

"As type of civilised countries Guizot selected France, not to encourage national vanity, but because, in prosperity, our country has ever disinterestedly lent the aid of her power and policy to the furtherance of generous ideas; because, in misfortune, she never lost respect for her dignity; because there is no great principle of civilisation that has not been harboured in France before it was diffused throughout the world; because, rich in forces and ideas, she has always placed her forces at the service of her ideas; because our language, our habits, and sympathetic spirit, have rendered ours the fittest of nations to march at the head of civilisation."

But it is not often that the orator allows himself to be carried to such an extreme. Dumas is by no means blind to the little weaknesses of his countrymen, which he occasionally touches with fine satire.

In the commemoration address on Geoffroy Saint-Hilaire, he contrasts the domestic animals with the number of species not domesticated. "Losing sight," he says, "of the domestic animals not possessed by France, there are not more than about thirty that we have actually appropriated, and since we are in the habit of considering ourselves the centre of creation, we might say that for each useful species, nature has not provided less than 5,000 or 6,000 that are good for nothing, since we derive no direct profit from them." There exists no doubt as to the sense in which Dumas speaks of the centre of creation.

On the other hand, whenever he sees room for improvement, he never hesitates to hold out other nations as examples to his countrymen. Speaking before the Chamber of Deputies long before the revolution of February,—"As to form," he said, "the French coinage—it is a misfortune to be acknowledged in order to be repaired—the French coinage is below the coinage of England, which is inferior to that of Germany. It consequently is, to-day, the worst coinage in all Europe."

Again, when in the Clermont address, to which we have alluded, he wishes to impress his countrymen with the impulse scientific movement in France is likely to receive from the establishment of a French Association, how eloquent an encomium does he bestow on the sister institution in England! How well does he depict the beneficially decentralising influence of the British Association! How candidly does he acknowledge the necessity of a similar influence in France, and how strongly does he urge his fellow-citizens to follow the noble example set by Old England!

. . . . "Science and art are money! This twofold truth was understood; the English universities reformed their instruction; numerous schools of design were created; colleges of practical science multiplied. The British Association, taking the lead in this movement of opinion, so far as concerns the sciences, has not ceased since then to diffuse the taste for natural philosophy amongst men of the world, and, in view of its advances, to excite the zeal of all the enlightened spirits of the United Kingdom. The example thus given it was worth our while to observe and to follow. This association, which has served for our model, is already half a century old, and English science has resumed its wonted rank through the impulse thus received. This is a fit opportunity to describe its manner of procedure.

"The British Association receives no subsidy from the State, but relying solely on private support, it unites by strong ties the aristocracy of science with that of rank and of fortune, and thus makes the disinterested aspirations of *savants*, the prudent calculations of merchants and manufacturers, the goodwill of men of the world and the

wisdom of statesmen acting in a private capacity, all tend to a common goal.

"Alongside of the professors in its universities, England sees the names of all the representatives of its ancient families figure on the lists of the British Association; while members of the House of Lords alternate with the masters of science in the president's chair. Prince Albert, shut out from political life by the laws of his adopted country, set an example well worthy of imitation, by throwing himself actively into the work of the Association. After his arrival in England, he placed at its service the prestige of his position, and by a just return has received the reward of cordial popularity. It is thus that in this aristocratic republic, the ancient English nobility preserves its influence over public opinion, which is accustomed to see it in the front ranks when the nation's greatness is in question, figuring at the head of troops on the battle-field, commanding ships of war in naval contests, defending foreign commerce, promoting by its example the progress of agriculture, realising by its capital industrial novelties, elucidating by personal labour the speculations of pure science, and giving everywhere an example of work, of devotion, and of patriotism. It is thus that there is founded a power of which we may say that if it does not will all that it can do in what concerns others, it can do all that it will when its own interests are at stake.

"The British Association, since its institution, has defined its ground, taken possession of it resolutely, and never relinquished it. Without interfering with the course of other institutions in the country, it gives a strong impulse and a more systematic direction to scientific researches. It facilitates the connection of persons devoted to the cultivation of science in different parts of the United Kingdom, with one another and with foreign men of science; it calls general attention to all subjects relating to the sciences, and removes every obstacle of a public nature which might stop or retard their progress. Such was its programme, such has remained its rule.

"The British Association meets every year for a session of eight days, sometimes in one of the towns illustrious through the renown of venerable universities, sometimes in one of the important manufacturing centres of the kingdom, or in one of the geological districts which the discussions of the moment have marked out as of interest to the learned world. When I took part for the first time, some forty years ago, in one of these sessions, I found a spectacle full of instruction. In France, intellectual life seemed then to concentrate itself more and more at Paris; in England, alongside of Cambridge, of Oxford, of Edinburgh, and of Glasgow, London was not to be counted. In France science appeared made for the learned only; in England it stirred the interest of the people. In France every professor sent to the provinces looked on himself as an exile: in England it would startle a professor of a provincial university to hear that he had been called to London by way of advancement.

"The centralisation which drew everything to Paris presented a complete contrast to this independence which animated the provincial towns of England. To-day, however, everything tends to place the two countries in equilibrium. London possesses its university, founded by the subscriptions of friends of progress; and France on its side sees its provincial universities revive under the protection of the State, and is sanguine of the future of those ancient institutions whose restoration has long occupied the best spirits of the nation. Napoleon I., full of solicitude for the Institute, one day directed his Minister of the Interior to take certain measures in favour of the body to which he prided himself on belonging; 'I obey,' said the Minister, 'but I should prefer receiving an order to place two pieces of artillery charged with grape on the Pont des Arts.' 'And why so?' 'To send all our *savants* into the provinces to reconstitute our ancient centres of study.' The result sought was too absolute and the means too violent. Paris must have its share in scientific institutions. The new measures are preferable. Paris still keeps the institutions which time has consecrated; and the departments recover a good of which they ought never to have been dispossessed, and whose value they will henceforth know by having been so long deprived of it."

The Clermont address contains another passage which we cannot refrain from quoting; for it illustrates Dumas's notions on human happiness and thus affords us a welcome insight into his views of life. We are delighted to learn that, however varied the lines of mental activity along which his rare gifts have led him, however manifold in consequence his avocations, the heart of Dumas never ceased to belong to science.

. . . "Truth is beautiful enough in itself to merit a homage abstract and pure, the *rôle* of science noble enough to satisfy the aspirations of the most exalted intellects; its field vast enough to offer a harvest to every worker; some cut down rich crops, others are content to glean; but that which each gathers or discovers all enjoy; among men of science goods are in common, and the torch, kindled by genius, is not extinguished, even when it has communicated, from place to place, its fruitful flame to the entire world.

"Allow me to add that the recollections of an already long life have permitted me to become acquainted with a great variety of personages. And if I call on memory to picture to me how the type of true happiness is realised on earth, I do not see it under the form of the powerful man clothed in high authority, nor under that of the rich man to whom the splendours of luxury and the delicacies of well-being are granted, but under that of the man of science who consecrates his life to penetrating the secrets of nature and to the discovery of new truths. Laplace, following out, for half a century, the application of the laws of the cosmic system to the movements of celestial bodies; Cuvier, inventing comparative anatomy and creating anew the ancient population of the globe; De Candolle, writing the elementary theory of botany and the description of all the known plants; Brongniart, showing how to classify soils by the fossils characterising them—these illustrious men of science and others, who, taking them as models, have done honour to your city, and whose names are on all your lips, have known a happy life. Animated by the love of truth and indifferent to the enjoyments of fortune they have found their reward in public esteem."

With these eloquent words, from which, much more than from any observations we could make, the noble character of Dumas is reflected, we conclude our gleanings from his writings.

A life of rich achievement lies unrolled before us, a life of service to science devoted to the great ends of humanity. And while we admire the amount and diversity of work Dumas has accomplished, the unbroken continuity of his productive activity fills us with astonishment. His labours follow one another like pearls on a string, and—whether opening up new fields of investigation or pathfinding in old ones—are always luminous models of keen observation and conclusive logic. And if the mind rejoices in these creations, undecided whether it feels itself more attracted by the originality and importance of their substance, or by the splendour and perfection of their form, not less does it cheer the heart to know that their author is still amongst the living in unimpaired bodily strength and mental vigour. May the noble veteran be yet destined, for long years to come, to look back with just pride on the glorious course he has traversed, and to intertwine many a new leaf into the rich garland of his memories!

A. W. HOFMANN